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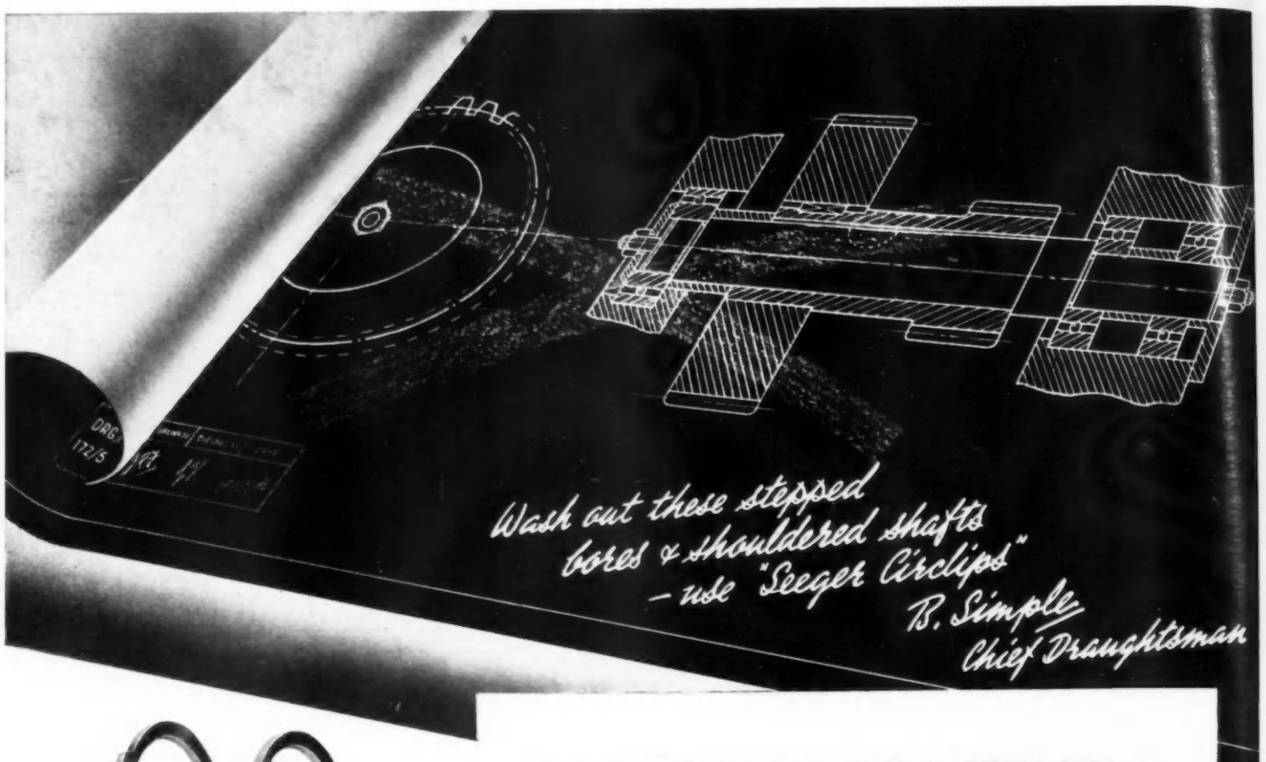

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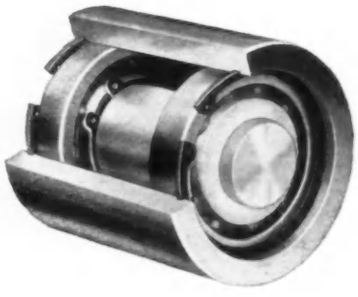

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THE CONTROL OF POWER IN LARGE INTER-CONNECTED ELECTRIC SUPPLY SYSTEMS.

By T. F. WALL, D.Sc.

(*Continued from page* 84.)

CIRCUIT-BREAKER PHENOMENA.

§20. *High-Tension Alternating-Current Circuit Breakers.*—The cooling and good insulation characteristics, as well as the high breakdown strength, of oil make it possible to quench rapidly very large alternating-current arcs. As the switch contacts separate, the total current to be interrupted becomes concentrated at the points of contact and the high current density will then heat these surfaces to incandescence and so create an arc. Owing to the very high temperature of the arc, the oil adjacent to the contacts becomes volatilised and gives rise to a gas balloon exerting a pressure outwards in all directions. The pressure in this balloon may reach a value of some hundreds of atmospheres. This gas pressure causes compression of the air-cushion above the oil surface, so that the air is forced out of the vents provided in the cover of the oil container. When the current passes through zero the arc goes out. If the gap between the switch contacts is then sufficiently great, so that the gas balloon does not cover the contact surfaces, cooling oil will flow over these surfaces and the breakdown strength of the oil will prevent the arc from reforming; that is to say, the current will have been effectively interrupted. If, however, the gas balloon does not move away sufficiently rapidly, the contact surfaces will remain incandescent and the arc will re-strike as the p.d. wave rises. Since the generation of the gas balloon from a very small volume of oil acts, in effect, like an explosion, the possibility arises that, as the air passes through the vents, oil may become trapped in these vents, sealing them, so that the gas balloon can only increase the pressure of the air-cushion. If in extreme cases the balloon remains in the neighbourhood of the contacts, the arc will persist and generate more gas until the pressure bursts the container. If the gas of the balloon reaches the oil surface and mixes with a certain amount of air, a spontaneously inflammable and explosive gas is formed, which may give rise to disastrous consequences.

It will be seen that, for a given distance of travel and for a given speed of travel, the pressure developed in the tank will be smaller the greater the air volume which exists above the oil before the switch starts to open. In this way it is possible, within limits, to vary the pressure which is developed in the switch tank. Since the oil cannot escape in any appreciable amount from the vents, the magnitude of this pressure, in practice, is of the order of seven atmospheres. If the arc does not form at a sufficient depth in the oil, the gases will not be sufficiently cooled during their passage to the surface and may then become ignited on emerging from the surface of the oil. Even when the arc is formed deep down in the oil, an explosion of these gases may be caused by drops of molten metal splashing into them or by an electric spark passing through them. Formerly, switches for the control of electric power systems were exclusively oil switches, and an example of such a switch is shown in Fig. 43. For low and medium voltages three such switches may be arranged in the same oil tank, while for high voltages the switch for each pole would operate in a separate tank. The most exacting conditions under which a circuit breaker must operate are those of a short-circuit, and, particularly, a short-circuit at full excitation of the generator. Transient currents may then be developed having a magnitude many times greater than the normal current of the system. In consequence, the energy which must be dissipated at the contact surfaces, and so absorbed by the oil, becomes immensely greater than that corresponding to the normal current. Just before the contacts meet when the switch is being closed, the arc will start. If the contacts are worn, or are somewhat out of alignment, actual connection is made by isolated minute surface areas, thus giving very high current densities which may melt the contacts at these hot spots. The electromagnetic forces due to a short-circuit current may then operate on these bridging arcs so that under certain conditions the switch may never become effectively closed. If the switch remains in this condition with the arc persisting, the molten places on the contact surfaces may become welded together so that the switch is put completely out of action.

Fig. 43.

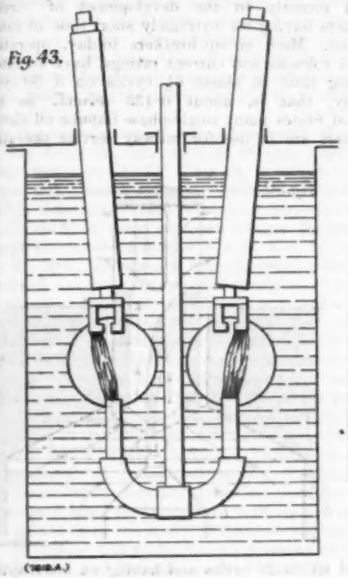


Fig. 44.

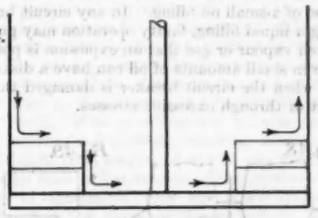


Fig. 45.

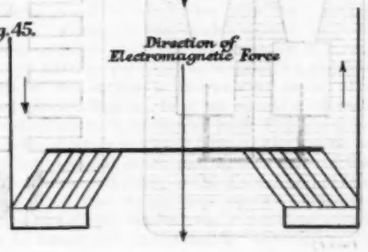


Fig. 46.

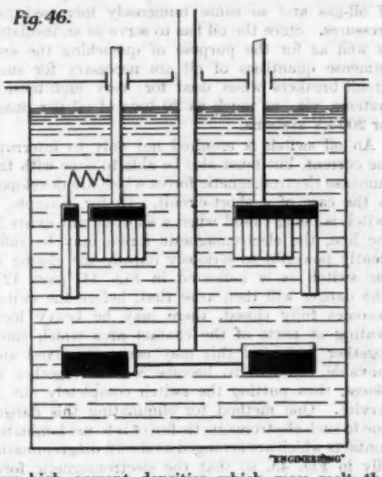


Fig. 47a.

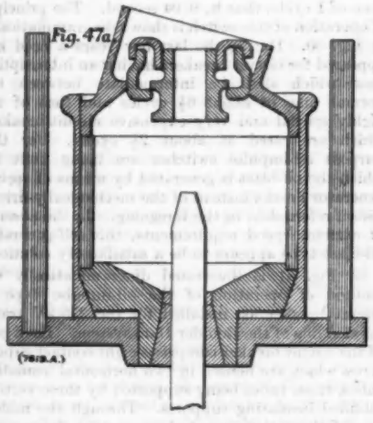
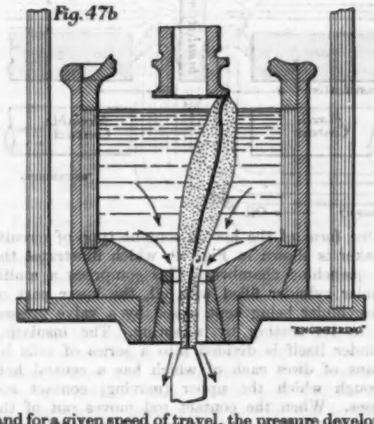


Fig. 47b.



Some years ago, it was the practice to delay for a few seconds the opening of the circuit breaker so that the heavy transient currents could die away and thus reduce the demands on the circuit breaker, not only because the current to be interrupted will become greatly reduced in this way, but the demagnetising effect of the armature reaction will have had time to produce a corresponding reduction of the generator e.m.f. Nowadays, however, it is required that the circuit breaker shall start to interrupt the current immediately, even under the most drastic conditions of a sudden short-circuit. Since the hot gases formed by the arc are formed in a small fraction of one half-cycle, the sudden volatilisation and decomposition of the oil has an explosive effect, as already pointed out. In this way, pressures are developed which may range from tens to hundreds of atmospheres. This pressure will travel as a spherical wave outwards through the oil, the pressure becoming correspondingly reduced as the sphere expands. Nevertheless, the pressure at which the sphere reaches the container walls may be large enough to distort or even to crack the structure. When the pressure wave reaches the surface of the oil, it will throw up a fountain of oil and this effect may be repeated at each half-cycle and produce highly undesirable consequences.

As a result of numerous tests on the amount of oil gas which is produced by an electric arc, it has been found that about 50 c.c. of gas are formed per kilowatt-second of electrical energy dissipated in the oil. Hence, if a short-circuit of $0{\cdot}5 \times 10^6$ kVA is interrupted in about $1\frac{1}{2}$ cycles, that is, in 0·03 second, and if a ratio of arc-burning pressure to arc-ignition pressure of 5 per cent. is assumed, it can be shown that the energy developed will be

$$U = \frac{1}{\pi} \cdot \frac{3}{100} \cdot \frac{5}{100} \cdot \frac{10^6}{2} = 340 \text{ kW. sec.}$$

so that about 12 litres of oil-gas at normal temperature and pressure will be formed. If the initial

pressure produced by the arc is 20 atmospheres and the temperature is 5,500 deg. C., that is, 20 times the absolute normal temperature of 273 deg. C., then these two opposing effects on the volume will cancel each other so that the initial volume of gas will be 12 litres, as stated above. If each pole has a double-break contact, that is, six breaks in all for the three phases, then each break will give rise to two litres of gas and this will produce a gas balloon of about 15·5 cm. diameter. The requisite dimensions of the oil-tank will be governed by these considerations of the amount of gas generated. If the gas balloons from the neighbouring poles coalesce, then the arc may remain unquenched and this will give rise to continually increasing volumes of oil-gas and so cause immensely increased gas pressures. Since the oil has to serve as an insulator as well as for the purpose of quenching the arc, immense quantities of oil are necessary for such circuit breakers when used for very high-tension systems, viz., as much as 20 tons of oil per phase for 200-kV systems.

An oil switch is required not only to interrupt the current, but must also be able to cope with the immense electromagnetic forces which are developed in the case of a short-circuit. If, for example, a switch is being closed when a short-circuit exists in the line, the electromagnetic forces may be sufficiently powerful to seriously impede the closing of the switch as is indicated in Fig. 44, page 121. The danger will then arise that, before the switch becomes fully closed, there may be heavy local heating at parts of the contact area which come together first, and this may cause the fixed and movable contacts to become welded together at places, thus putting the switch completely out of service. One method for eliminating this danger due to such electromagnetic forces is to use laminated contacts which are arranged as shown diagrammatically in Fig. 45, so that the electromagnetic force will act in the direction tending to close the switch. In order to pass as quickly as possible through the danger zone of preliminary surface contact, the switch must be closed at a high speed. Protective resistances are also incorporated in series with a supplementary contact, as shown in Fig. 46. Such an arrangement is also a most effective method of suppressing powerful pressure surges which may be developed when a circuit is switched in or out.

An important practical form of the laminated contact principle is the so-called "tulip" type which is used when the movable contact is a rod instead of a blade. In this type the contact is of circular form and is radially laminated so that the electromagnetic forces press these segments on to the movable contact rod which they embrace.

In Fig. 47(*a*), page 121, is shown the arc-quenching chamber of an oil-switch. In this arrangement, as the movable rod is withdrawn from the tulip contact, the consequent arc generates oil gas at a pressure of from 60 to 80 atmospheres. As the stem leaves the quenching chamber (see Fig. 47*b*), the oil gas surges out and drags the oil with it; in this way the arc is powerfully cooled and quenched. In Fig. 48, on this page, is shown diagrammatically an oil switch with quenching chambers in position.

§21. *Oil-Switches with Low Oil-Content.*—It has been pointed out in §20 that in the oil-tank type of circuit breaker the oil is used not only for the purpose of extinguishing the arc, but also to insulate the contacts from each other and from earth so that it is not practicable to reduce the oil filling in such switches by any change in design, especially in the case of switches which are used on very high voltage systems. Although oil circuit breakers have a long history of reliable operation, every switchgear plant in which such switches are used requires special structural precautions in order to provide against the effects of oil-gas explosions and these requirements impose corresponding difficulties which, in the case of very high voltage switches, become of a formidable nature. In recent years the linking up of large power stations and distribution networks has resulted in the concentration and control of such vast amounts of energy that the demands upon the necessary circuit-breakers have become almost incredibly severe.

The last decade has witnessed revolutionary changes in the technique of switchgear design, the primary cause of these developments being the fact that several severe explosions of circuit breakers have had far-reaching effects upon the operation of the system and in some cases have caused the death of members of the control staff. In recent years, therefore, strenuous efforts have been made to eliminate oil from circuit breakers and switchgear generally; a notable step forward was the introduction of the circuit breaker with a small oil filling. The amount of oil for this type of switch is only about one hundredth of that for the oil-tank switch of corresponding characteristics, because the oil-filling is only used to extinguish the arc, the insulation from earth being provided by means of porcelain insulating pillars. It is to be observed, however, that the fundamental drawbacks of the oil-tank switch are only reduced but not eliminated by the use of a small oil filling. In any circuit breaker having a liquid filling, faulty operation may produce so much vapour or gas that an explosion is possible, and even small amounts of oil can have a disastrous effect when the circuit breaker is damaged through a fault or through excessive stresses.

Fig. 48.

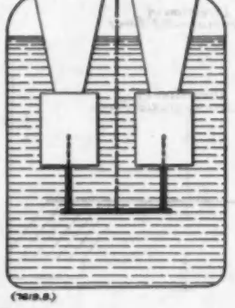


Fig. 49.

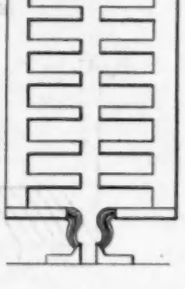


Fig. 50.

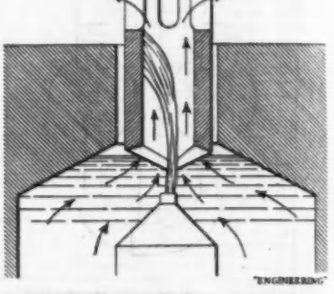
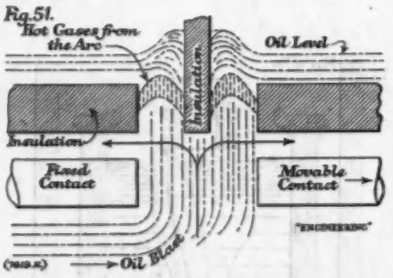


Fig. 51.



One form of the low oil-content type of circuit-breaker is shown in Fig. 49, which illustrates the arc-quenching chamber. This comprises a multi-cellular cylinder filled with oil, the lower part of the cylinder being kept closed by a valve pressed on to its seating by a spring. The insulating cylinder itself is divided into a series of cells by means of discs each of which has a central hole through which the upper (moving) contact rod passes. When the contact rod moves out of the lower (fixed) tulip contact, an arc is initiated and in consequence, a bubble of high pressure gas is formed. This gas bubble cannot develop into one large balloon as in the oil-tank switch (Fig. 43), since it is divided among the cylinder cells and presses against the walls of the cylinder so that it becomes effectively cooled. In the case of very heavy currents, the amount of gas, as well as the gas pressure, is increased to such an extent that the cylinder valve opens against the spring and the gas escapes out of the chamber and carries with it oil fragments which pass along the path of the arc and effectively cool it to extinction. This process takes place at a very high speed, so that the arc can be extinguished in from three to four half-cycles. Since the oil is only used for quenching the arc, a small amount only is adequate; the insulation from earth is provided for by insulating columns.

Another example of the use of a low oil-content type for arc extinction is the so-called "oil impulse" circuit breaker used on the transmission line at 287 kV from Boulder Dam to Los Angeles, as well as on the 138-kV side of the auto-transformers at the Los Angeles end of that line. These breakers are capable of operating with an extremely low time rating, viz., within three cycles of the 60 frequency supply, that is, within 0·05 second. This time is measured from the moment at which the relay trip coil becomes energised to the moment at which the arc is extinguished. In these breakers the arc is extinguished by a blast of cold oil which is driven across the arc by means of a mechanically-operated piston.

The time required for a circuit breaker to interrupt a circuit is a most vital part of the time necessary to clear a short-circuit and much attention has been given recently to the development of circuit breakers having an extremely short time of interruption. Most circuit breakers to-day, operating on all voltages and current ratings, have an interrupting time of about 6½ cycles on a 50-cycle supply, that is, about 0·133 second. In the United States many single-phase impulse oil circuit breakers are in use for railway service operating on 11 kV at 25 cycles and having an interrupting time of 1 cycle, that is, 0·04 second. The principle of operation of this switch is shown diagrammatically in Fig. 50. During the last few years a need has appeared for circuit breakers having an interrupting time which shall be intermediate between the normal time of about 6½ cycles and that of the highly special and very expensive circuit breakers which are rated at about 2½ cycles. For this purpose oil-impulse switches are being built for which the oil-blast is generated by means of special generator breaks instead of the mechanically-driven piston referred to in the foregoing. In the absence of extreme speed requirements, this self-generated oil-blast type appears to be a satisfactory solution.

In Fig. 51 is illustrated diagrammatically the method of operation of the oil-impulse type of circuit breaker as installed for the 275-kV transmission line of the Boulder Dam system. Each pole of the circuit breaker comprises eight contact gaps in series which are housed in two horizontal insulating tubes, these tubes being supported by three vertical oil-filled insulating supports. Through the middle one of these three vertical supports a driving rod passes while each of the two outer supports is provided with a current transformer. The horizontal insulating tube which houses the eight contact gaps is provided with a separating wall of insulating material capable of withstanding the destructive action of the arcing at the contacts, and this insulating wall has two holes over each of the eight gaps through which the oil-blast can pass so that a stream of oil is obtained in a direction at right angles to the arc. The oil-blast is driven by means of a piston which moves synchronously with the opening contacts and the oil pressure so produced is about six atmospheres. One of these three-pole circuit-breakers weighs about 50 tons, as compared with a normal oil-tank type which would weigh about 130 tons. The total amount of oil required for one circuit-breaker is about 9·5 cub. m., as compared with about 85 cub. m. for the oil-tank type. Since, however, only 800 litres of the oil is used for quenching the arcs this is less than 1 per cent. of that used in the oil-tank type.

(*To be continued.*)

RESEARCH IN TERRESTRIAL MAGNETISM.

THE collection of geophysical data, being essentially a co-operative enterprise involving the simultaneous operation of a network of observatories in conformity with a plan established by international agreement, is bound to suffer from the disorganisation caused by war conditions. Nevertheless, the report of the Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, covering the period from July 1, 1939, to June 30, 1940,* is an impressive record of achievement in the face of difficulties. It includes the initiation of fresh experimental projects, the continuance of the previous programme of field observations, the reduction of existing data, the organisation of and participation in several important congresses, and the publication of a large number of scientific papers.

An important innovation in geomagnetic observing has been the introduction of the magnetic 3-hour range index, K. This is a single-figure integer, and for each observing station a permanent scale is determined such that over an extended period, each of these stations assigns the same aggregate number of indices $K = 0$, $K = 1$, . . . $K = 9$. This furnishes a homogeneous series of records of the intensity of solar corpuscular radiation affecting the earth, useful both in regard to its influence on radio transmission and its bearings on solar activity. Violent magnetic storms with $K = 9$ occur only occasionally, near a sun-spot maximum, but only rarely is any full three-hour interval wholly exempt from disturbance. The period under review coincided with a maximum of the eleven-year sun-spot cycle and was marked by a magnetic storm on March 24, 1940, exceeding in violence any yet recorded. It caused widespread disturbance of wire and radio communications and considerable interference with electric power systems. Knowledge gained from the study of such records can be used to predict the probable occurrence of similar disturbances, and can also serve to indicate how electrical installations can be modified to minimise their effect. For this purpose, a wide-range magnetic recorder has been installed at Washington, capable of responding to greater variations than has previously been found possible. Something like 80 per cent. of the geomagnetic field can be accounted for by a single dipole of moment $8{\cdot}1 \times 10^{25}$ C.G.S. units, appropriately situated near the centre of the earth. The residual 20 per cent. of the field has been found to be representable, to within the accuracy of the observations, by a minimum of 14 radially directed dipoles, provided these are located midway between the centre and surface of the earth. This depth is that at which seismological evidence indicates a discontinuity in the elastic properties of the earth, and the fact that this residual field would appear to originate in this region is of obvious significance in connection with any theory concerning its origin. A similar representation of the field of the magnetic secular variation was also developed, the corresponding dipoles being of equal intensity and located at the same depth. The two systems of dipoles postulated to account for the residual and the secular variation field tend to be orthogonal. The average strength of the dipoles of the residual field is one-eightieth of that of the centrally situated dipole, while the dipoles of the secular variation field are about one-hundredth as strong as those of the residual field.

The analysis of complicated fields, such as those arising during magnetic storms, by the Gaussian method of spherical harmonics is usually impracticable. A more fundamental method of procedure based on Green's theorem has been devised. This permits the separation of an observed surface magnetic field into its parts of external and internal origin by means of surface integrals, and is particularly useful in handling problems in which the data for reduction are presented in graphical rather than in analytical form. An application to the field of magnetic storms indicates that something like 60 per cent. of the observed field is of external origin and that departures from this value are greatest near the auroral zone.

With the aid of a cascade high-pressure bomb, hydrostatic pressures in excess of 200,000 atmospheres were attained at the Geophysical Laboratory. This apparatus renders possible the investigation of the magnetic properties of materials at pressures comparable with those actually existing in the earth's interior. For a specimen of cadmium-magnesium-iron spinel under a pressure of 10,000 atmospheres, a shift in the Curie temperature of as much as 5 deg. C. was observed. These measurements necessitated the development of an alternating-current bridge capable of responding to changes in inductance of 10^{-10} henry.

An experimental investigation of the upper atmosphere was made by measuring the light scattered from the beam of a modulated searchlight. The technique was refined to such an extent that it was possible to detect an amount of light of 10^{-14} watt in the presence of a background light of 10^{-10} watt. With a carbon arc, a 24-in. transmitting mirror, and a 30-in. receiving mirror, the scattered light from heights of 40 km. was detected. The results show a distribution of temperature and pressure in agreement with the observations of Hulbert. Another series of measurements, using 60-in. mirrors, was commenced.

One of the outstanding problems in atmospheric electricity arises in connection with the "supply current," which, in an undetermined manner, supplies negative electricity to the earth at a rate of about 1,800 amperes and so maintains a negative charge on the surface in fair-weather areas. The actual current flowing from air to earth in such areas depends to some extent upon meteorological and other more or less local factors, which must be taken into account in arriving at a measure of this supply current. A study of the diurnal and annual variation of the atmospheric electric-conduction current at College, Alaska, was undertaken with a view to tracing the corresponding variations in the supply current.

Harmonic analysis of the atmospheric electric data assembled at Watherloo (Western Australia) during the eleven-year period extending from 1924 to 1934 revealed a number of interesting features. As regards potential gradient, the 24-hour wave synchronised with that deduced from observations made over the ocean on board the yacht Carnegie, except for the wet months May to August. The 24-hour wave of the negative conductivity, however, exhibited a lag of something like an hour and a half as compared with that for the positive conductivity, and this must be related in some way to the ionic equilibrium in the atmosphere. The present lack of facilities for continuing magnetic observations over the oceans is mentioned as a matter of grave concern.

The electrical conductivity of the air depends mainly upon the concentration of small ions of molecular size. In a condition of equilibrium the latter will be the result of a balance between the rate of ion-formation and the sum of the rates of ion-destruction and ion-migration. It is doubtful, however, whether a state of strict ionic equilibrium ever exists in the atmosphere, and on this account the conception of equilibrium applies to the average rather than to the specific state. Accordingly, the measurements used in evaluating the parameters involved in the equations of ionic equilibrium must relate to an adequate sample and must be combined with due regard to statistical principles.

In an endeavour to secure more reliable measurements of the rate of ionisation in the atmosphere, a "thin-walled" ionisation chamber, designed for continuous registration, was employed. The ionisation in an enclosed space, measured in this manner, was found to be less when large ions were relatively numerous. The suggestion that these large ions, in falling, carry radioactive material down with them and thus tend to clear the air of ionising material was not confirmed by experiment. The rate of recombination of large ions, usually regarded as negligible in comparison with the other terms figuring in the equations for ionic equilibrium, was found to diminish with time by a factor of 25 in a period of an hour and a half after the formation of the ions, and is probably due to the progressive formation of larger ionic aggregates. Further study of the electrical phenomena associated with the evaporation and condensation of water revealed a discontinuity in contact potential of 0·26 volt when the outer layer of a frozen rain drop melts. The outer surface becomes more positive on melting and more negative on freezing, a result having an obvious bearing in connection with the electrification generated during thunderstorms.

In connection with the volcanological investigations planned by the Institution, a series of earth resistivity measurements was carried out with a view to determining the thickness of the extensive deposits of volcanic ash occurring in Guatemala. Depths extending to 600 m. were recorded.

Radio sounding methods have demonstrated the existence of three principal ionised strata, designated the E, F_1 and F_2 layers, in the earth's outer atmosphere. The major portion of this ionisation may be ascribed to emanations, partly waves and partly corpuscles, proceeding from the sun. There is also the possibility that the earth, in pursuing its orbit, may encounter streams of corpuscular radiation travelling in space. Contributions from other celestial bodies are comparatively small. One of the chief problems of ionospheric investigation is to determine the relative efficacy of the respective contributions from these sources and to ascertain the character of the corpuscular radiation. The collection of continuous data concerning ionospheric changes at a number of selected stations has been greatly facilitated by the development of an apparatus for the automatic recording of ionospheric structure.

Changes occurring within the E-region appear to be closely correlated with the diurnal geomagnetic fluctuations as specified in terms of the 3-hour range index, K, previously mentioned. Studies of this region included comparisons of the observed with the theoretically predicted values of the ion density at different locations as well as investigations of the special conditions associated with solar eclipses. The great magnetic storm of March 24, 1940, was accompanied by striking ionospheric changes. At the Huancayo (Peru) observatory the F_2-region moved up at the onset of the disturbance at a velocity between one-third and one-half the velocity of sound. Half an hour later, the ion density had fallen to less than 20 per cent. of its original value and ionisation in the F_2 region could be observed only at heights of the order of 1,000 km. Meanwhile a fresh F_2 region was in process of formation in place of that previously present, probably because of the continued incidence of ionising radiation. This enabled an estimate to be formed of the rate of production of ionisation in this particular region.

Some progress was made in applying a graphical method to reduce measured virtual heights of ionospheric regions to their actual heights. Fresh data concerning radio fade-outs were secured, and the study of the polarisation of waves returned from the ionosphere was continued.

Laboratory work in nuclear physics centred round the high-voltage electrostatic generator, which was induced to yield tensions up to 3·6 million volts, and the installation of a 60-in. cyclotron. Measurements were made on the scattering of slow and fast neutrons by collisions with protons, on the resonance scattering of protons by helium nuclei, and on the splitting of the deuterium nucleus into a proton and a neutron by high-energy γ-radiation. It is proposed to employ the cyclotron, when completed, in connection with work of a biological and chemical character, utilising the artificially radioactive isotopes of ordinary elements as tracers for following various reactions. A scheme for the adequate shielding of those operating the cyclotron from the powerful radiations generated by it has been worked out.

* *Annual Report of the Director of the Department of Terrestrial Magnetism.* Carnegie Institution of Washington. December 13, 1940.

EXPORTS OF AGRICULTURAL EQUIPMENT TO EIRE.—The United Kingdom Trade Commissioner at Dublin has reported that the Government of Eire has issued Orders providing for the suspension of the duties on iron or steel horseshoes and on agricultural machines and parts. The first Order extends from July 5 until further notice and the second from July 16 until December 31.

THE ENGINEERING INDUSTRY IN RUSSIA.

By V. A. BARY.

THE first weeks of the war between Germany and Russia have shown that the military equipment produced by the engineering industry of Russia has withstood its first serious test in a manner that was hardly expected by many critics of that country's recent history. Actual figures by which Russian engineering development can be gauged are not plentiful, and its extent can only be estimated on the basis of such circumstantial evidence as is provided by the brief war communiques, the few official observers' reports of the behaviour of mechanised equipment on manœuvres before the war, and the very general accounts that have been released of the progress of successive "Plans" for increasing industrialisation; but it is evident, from comparisons of these rather scanty data, that much has been accomplished, even though the efficiency of accomplishment may not have reached the standards which are now a matter of course in more technically advanced countries.

Russia is still primarily an agricultural country, and one of the first directions in which intensive mechanisation was pursued was that of providing tractors for farming purposes. This development suffered from various "teething troubles," as is well known; but these appear to have been surmounted, as, according to official figures, there were, in 1939, tractor stations to the number of 6,358 distributed over the 540,000 square miles of cultivated land. The number of the tractors themselves was not mentioned, but they must have been very large; and it is significant that they were stated to have been constructed entirely in Russia and by Russian engineers. A very rough check on the extent to which mechanisation has proceeded is to be found in the statistics relating to the number of horses in the country, which is stated to have fallen from between 27 millions and 28 millions in 1913 to only 17·1 millions in 1940, although the population is said to have increased by 12½ per cent. in the same period. Though these figures may be no more than approximately correct, they do indicate a considerable increase in the amount of mechanical motive power that has been made available; and, as there have been no imports of motor vehicles into Russia of anything like comparable magnitude, the conclusion is unavoidable that the Russian motor-vehicle industry has overcome the more serious of its difficulties and is now a major branch of engineering manufacture.

The article on Russian inland waterways, based on official information, which appeared on page 75, *ante*, sufficiently demonstrated the developments that have been made in this direction. The railway system, which has always operated under exceptional difficulties, compared with those of other countries, does not show an expansion that can be compared with that of the waterways, but it represents some 54,000 miles of track, though much of this must now be ineffective as a result of the war. Air transport of goods, passengers and mails has been intensively developed, however, and 69,000 miles of air routes were in operation at the outbreak of hostilities.

In the field of power generation, the exploitation of the Ukraine has been greatly extended by the hydro-electric developments on the River Dnieper, as is now well known. A new iron industry has been created, east of the Ural Mountains, as part of the general plan to safeguard the heavy industries of the country against attack from the West; and oil production, also, has been increased by the development of fields to the north-east of the Caspian Sea, though there is still some doubt whether the capacity is sufficient to make Russia self-supporting in this respect under war conditions. It is important to note that, while these developments have been aided by foreign experts from other European countries and from the United States, who have acted as advisers and sometimes as supervisors of the actual work of construction, the greater part of the work has been performed by Russian engineers, especially in more recent years. That the rank and file of the engineering tradesmen and technicians are fully capable of carrying out great undertakings of this kind, the writer sees no reason to doubt, having been engaged for many years in the direction of civil and mechanical engineering work in many parts of the country, from the shores of the Baltic to the borders of Turkestan.

Until the Eighteenth Century, timber was the basic material of all Russian engineering works, and the skill of the carpenters who were the architects and builders of the old Russia was and remained of the highest standard of craftsmanship. The founder of the Russian Empire, Peter the Great (1689-1725), who was nicknamed *Tsar-Plotnik* (Tsar-Carpenter), introduced radical changes in the social system of the country and began to develop various industries on European lines. Iron foundries and, later, steel production, came into being. The engineering employees were mostly recruited from the great Volga waterway regions, where a shipbuilding industry had existed for centuries, producing not only trading vessels, but also fighting craft, used against the Persians across the Caspian Sea. This region, extending from the Baltic to beyond the Ural Mountains in the east, and approaching Persia and the Black Sea to the south, was served by the carpenters from the north. The first Russian iron and steel industry was established in the central part of the Volga basin and in the Urals. Until the South of Russia developed its own coal and steel industry, the north was the only provider of these commodities; hence the priority of the northern carpenters among the Russian engineering trades.

These carpenter-engineers were self-educated and largely self-trained, but unquestionably they were highly skilled craftsmen. As an instance of the quality of their handiwork the fact may be mentioned that, when the first steel tankers to carry paraffin from Baku up the Volga were built in 1880 by the writer's father, the late Mr. Alex. B. Bary, the wooden-ship builders maintained a vigorous, and for some time quite a successful, rivalry with wooden tankers, ranging in displacement up to several thousand tons; a considerable feat, by men who owed nothing to technical-school education. Similar resistance to iron and steel was offered in bridge building and other branches of structural engineering. The makers of cutlery and steel tools, and the locksmiths, from the same Volga-Oka region and the Urals used to compete in the quality of their products with those of Sheffield and of Solingen; and the iron castings turned out in these districts astonished visitors from foreign countries by their high quality and extreme cheapness. Art castings in iron, from the Ural district, frequently won the highest awards at exhibitions held in other countries. The fact was that the workmen from those parts of Russia were descended from generations of guild craftsmen; so that it is only to be expected that their successors of the present day should show a certain inherited talent when the directing organisation had become sufficiently stabilised to enable them to apply it.

After the reforms instituted by Peter the Great in the first quarter of the Eighteenth Century, the process of unifying Russia and developing Russian industries continued for some 200 years by methods which were very much of Prussian character; and, after the Russo-Japanese war, German influence extended, exerting a strong economic pressure which culminated in the German-Russian tariff agreement. This agreement, which was to have terminated on December 31, 1915, had war not broken out in 1914, marked the beginning of the definite breach between the two countries and led to the first real *rapprochement* between Russia and Great Britain. The Krupp influence in Russian industry waned, and, instead, agreements were made with British firms to establish, for example, shipyards on the Black Sea and armament works in the Volga basin. The European political tension of 1911, associated with the Agadir incident in Morocco, strengthened Russia's determination to throw off the German economic grip; and, in 1913, in preparation for the revision of the German-Russian trade agreement, plans were made to hold an All-Russian Trade and Industry Exhibition in 1915. As vice-president of the Russian-American Chamber of Commerce and a member of Council of the Manufacturers' Association in Moscow, the writer was closely concerned with these preliminary arrangements and was able to observe the dissension which then existed in the Russian engineering industry as a result of German penetration, and the efforts that were being made to counteract German influence.

Already, before 1914, these efforts were meeting with a certain amount of success; for example, there were more large Diesel engines in use in Russia at that time than in any other country. Certainly, Germany was the main supplier of such engines, but in Russia itself large-size units were being produced in at least seven engineering works in Leningrad (then St. Petersburg), in the Moscow district, and in Kharkoff, in the Ukraine. Cargo vessels and well-equipped passenger ships of considerable tonnage, fitted with Diesel engines of Russian make, were in service on the Volga. At that time, the Russian Ministry of Transport and, to a certain extent, the other State purchasing departments, had ceased to buy from foreign countries and were using home-produced material exclusively. The output of agricultural machinery increased steadily from 1910 onwards, and, in every direction, during the years preceding the 1914 war, there was a marked industrial expansion, quite apart from the growing armaments programme undertaken by the Government. The same policy of promoting industrial self-sufficiency has been pursued during the past twenty years. It proceeded slowly at first, and many mistakes were made, but the work of building up industry has been pressed forward with great vigour and a considerable measure of success. It may have been observed that, for several years, Russian imports have been mainly machinery, either for the generation of power, or in the form of machine tools with which to apply the power to production.

In 1913, the Russian iron and steel industry produced only about 5,000,000 tons. Germany's investments in those industries were practically nil, most of the foreign capital having been provided by Belgium, Great Britain and France; but, as a result of the preferential tariff agreement between Germany and Russia, the output of steel plates and rails, and of steel tubing, was actually controlled by syndicates and cartels with headquarters in Berlin. In 1938, according to official figures, the Russian output of iron and steel was in excess of 25,500,000 tons, as compared with the 35,000,000 tons produced in Germany. These commodities are the basic materials of engineering and the comparative figures afford some idea of the growth of the engineering industry over the same period of time. In 1913, the number of persons employed in manufacturing industry was between 2,500,000 and 2,600,000; whereas the number of recorded for 1938 reached 25,000,000, and is reasonably certain to have been increased since the outbreak of war in 1939. Of the total of 25,000,000, the heavy industries were stated to employ 7,065,000, the building industry some 2,203,000, and mechanised farming and the thousands of tractor stations, not less than 2,837,000. Qualified engineers and technicians, the same returns showed, numbered rather more than 584,000. The results of the fighting on Russia's western frontiers, even to the little extent that they are accurately known, show that the engineering industries of the nation are now capable of considerable and sustained output; and that the personnel responsible have attained a standard of competence very different from that which marked the beginning of the various "Plans," and are not unworthy successors of the individual craftsmen—whom, it is to be hoped, they have not entirely supplanted.

EXPORT OF MANUFACTURES OF HEMP.—The Board of Trade has made the Export of Goods (Control) (No. 25) Order, 1941 (S.R. & O., 1941, No. 1103, price 1d.), which came into force on August 1. Under the terms of this Order the existing export licensing requirements with respect to cables and ropes, and cordage and twine of hard hemp; hemp of all kinds, including false hemp; manufactures wholly or partly of soft hemp; and hemp yarns, are superseded by the provision that licences will, in future, be required to export hemp of all kinds, and manufactures wholly or partly thereof, to any destination abroad. Applications for licences should be made to the Jute Trade Adviser to the Export Licensing Department, 56, Reform-street, Dundee.

BRITISH NATIONAL SPECIFICATIONS FOR CAST IRON.*

By J. G. PEARCE, M.Sc.

THE establishment, in 1928, of the first national specification for general grey-iron castings (B.S.S. 321-1928), with which the original Test-Bar Committee of this Institute was actively concerned, was a landmark in the history of cast-iron testing. Among the revolutionary features of this specification were: (1) the introduction of the tensile test for use in parallel with the transverse test, previously used almost exclusively; (2) the adoption of cylindrical test-bars, rendering obsolete the rectangular and square bars previously used, accompanied by the option of machining the transverse bar; (3) the acceptance of the principle of adjusting size of bar to section of casting represented by it; and (4) the adoption of test-bars cast separately from the casting. In addition, the specification powerfully reinforced the principle that, for general purposes, iron castings should be specified by their mechanical properties, and that composition should be left to the discretion of the founder.

Fig. 1.

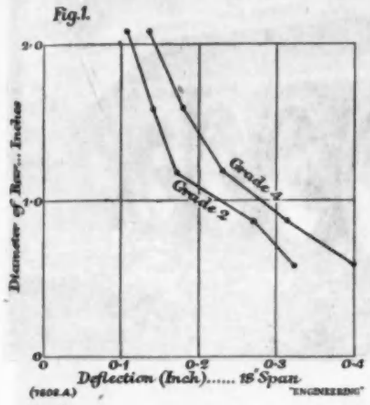
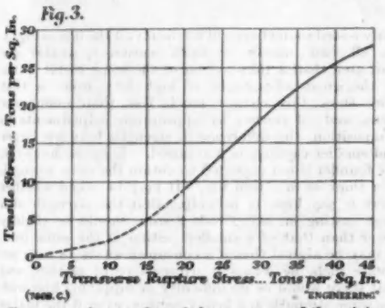


Fig. 3.



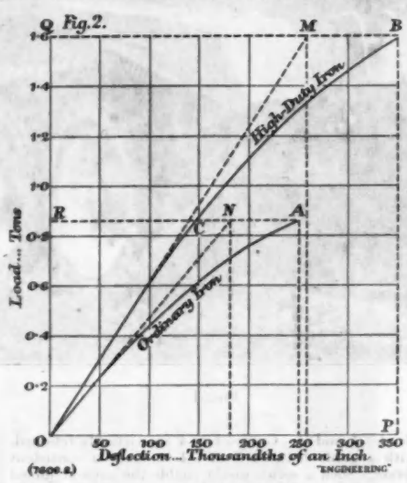
Experience has confirmed the accuracy of the original basis, which has been extended, and, in minor degrees, modified. To-day there are six grades of iron covered in two specifications, No. 321 and No. 786, ranging from 9 tons to 26 tons per square inch in tension, and five test-bar sizes in place of the original three. As was hoped, the basis of testing has been adopted both in new and in revisions of earlier B.S. Specifications. It has had repercussions abroad. A great deal of experience has now been recorded on the round bar, to be found in British, United States and Continental sources. The war has given an enormous impetus to the use of these specifications, both for new products and for cast-iron replacements of other materials. Their existence has been a great advantage to the industry.

In some quarters, a demand for revision has been expressed, to take care of the minor inconsistencies arising from the growth of the specification on a basis of experience and the inevitable compromises of committee working. Attention has been drawn, for example, to the gap between the highest grade in No. 321 and the lowest in No. 786; to the fact that the transverse strengths do not entirely line up with the tensile strengths, and to the fact that the lowest grade of No. 786 is not normally accepted as high-duty iron. Such a revision must wait on events, but it may be of interest to foreshadow some directions in which improvement may be made and to furnish a basis for discussion.

Skin-machining transverse test bars gives a rather better result, and, what is perhaps more important, more consistent results from a series of bars. This may be due to the removal of the stressed skin, especially from green-sand moulds. The effect is less pronounced in bars from dry-sand or core-sand moulds. If more than about 0·10 in. on the diameter is removed, the strength may begin to fall. The conversion of transverse breaking loads to rupture stress is now widely followed. The specifications provide for the conversion of breaking loads obtained on an actual bar, not cast quite to size, to those expected from the corresponding standard bar. The conversion of breaking loads on one standard bar to what might be expected on another standard bar differing in diameter leads, however, to erroneous results, because transverse stress changes with size.

The deflection figure gives a valuable indication of toughness, but its value is obscured by diameter and span variation in test-bars and by changes consequent on the change in quality between various grades. At present, deflection is regarded principally as an indication of regularity in manufacture, rather than as of intrinsic value, although it has such a value. If the test bar be considered as a beam under load, the deflection is directly proportional to the square of the span; if the span is doubled, the deflection is quadrupled. As the diameter of bar increases, the deflection diminishes for a constant span, and in practice the deflection can be taken as inversely proportional to the diameter of the bar, the product of diameter and deflection being approximately constant. Bars can therefore be readily compared with respect to deflection, even if spans and testing diameters differ. To illustrate this point, the deflections are given in Table I, herewith, for the various sizes of bar in Grade 2 and in the new Grade 4 of B.S.S. No. 786. The deflection figures are then given for a uniform span of 18 in. on all sizes, and Fig. 1, on this page, shows how the diameter changes with deflection for a constant span. Such curves can be constructed for all grades, and facilitate the fixing of consistent deflection figures. Table I also gives the product of deflection and diameter. The slight inconsistency in the Grade 2 figures is at once evident from Fig. 1, the deflection being slightly low on the 1·2-in. bar and slightly high on the 0·875-in. bar.

Fig. 2.



The statements above, relating to the test-bar as a beam, are strictly true only if the bar is an ideal beam, which is not the case. Consider loading a transverse bar to a point short of fracture. On removal of the load, the bar appears to return to its original position. If it returned fully, the bar would be wholly elastic and these statements would then apply. It is found, however, that, on removal of the load, there is a small permanent deflection or set. This can be used to estimate the proportion of permanent deflection or set in the total deflection at fracture. The remainder, which disappears on removal of the load, is elastic deflection; in ordinary engineering irons about 75 per cent. of the total deflection is elastic and the remainder is permanent set. These two components enable one to distinguish between brittle and tough irons; for rigid or brittle irons have a low permanent set, and tough irons a high permanent set, as do irons having a high resistance to shock. In an open-grained iron, the proportion of elastic to total deflection may fall to 60 per cent., and in a very rigid iron, rise to 90 per cent. The total deflection increases at a greater rate than the load. The elastic deflection increases at the same rate as the load, or at only a very slightly greater rate. Bars capable of withstanding higher loads prior to fracture, the tough irons, therefore have a higher proportion of permanent set in the total deflection.

In considering these components in relation to size of bar, the permanent set varies little from thick to thin bars, and therefore the curve showing changes in elastic deflection with diameter is approximately parallel with those shown, for example, in Fig. 1. In making use of beam formulæ for calculating stresses, elastic moduli, etc., the total deflection is more accurately replaced by elastic deflection. So far as design is concerned, however, at ordinary working loads there is only a very small difference between elastic deflection and total deflection, as the permanent set, under these conditions, is very low, and hence the error in taking total for elastic deflection is small. At fracture, the difference is considerable, and hence elastic moduli calculated from total deflection show large errors.

The difference between an ordinary engineering iron and a high-duty iron, under transverse loading is shown in Fig. 2, herewith. Increasing loads are measured along O Q, and the resulting increase in deflection is shown along O P. The engineering iron breaks at A and a load O R and with a deflection R A. The high duty iron breaks at B under a load O Q with a deflection Q B. It will be observed that at the load R, the high-duty iron has a deflection R C, considerably lower than that of the ordinary iron, R A. This is generally true of all close-textured dense irons, as compared with open or coarse-fractured irons. The difference lies almost wholly in the permanent set, and the latter show high permanent set, but early rupture.

The resistance to fracture of high-duty iron results in it breaking not only at a higher load, but also with a higher total deflection. The high-duty iron has a lower deflection per unit of load, but a greater total deflection. The superior properties of the high-duty iron have arisen from reducing the permanent set and thereby enabling greater elastic deflection to take place under load. The total deflection in ordinary comparisons may not appear to be greatly changed, but its character is, in fact, materially altered.

The significant change is the slope of the deflection line, that of the high-duty iron, represented by the tangent O M, being much more nearly vertical than that of the ordinary iron, represented by the tangent O N. Such a tangent drawn from the point O very closely approximates to the line showing elastic deflection, and the area of the rectangle so cut off gives a figure of merit for an iron with respect to this test, the product of load and elastic deflection. In Fig. 2 the high-duty iron is represented by the product O Q × Q M and the ordinary iron by the product of O R × R N. The figure of merit clearly increases with the quality of the iron.

The fact that a beam breaking transversely shows a higher specific stress than the same material broken in tension constitutes the beam paradox; for, in a material so much stronger in compression than in tension, transverse failure, due to a combination of tensile and compressive stresses, must fundamentally be a tensile failure. There is a reasonably regular relation between tensile and transverse stresses. If the transverse rupture stress is designated R, and the ultimate tensile stress T, both in tons per square inch, the ratio $\frac{R}{T}$ is not constant. The relation varies between 1·5 to 2·2, being usually 1·8 to 2·0. The author later found that the expression $R = T + 11$ was more satisfactory, and this was used in B.S.S. No. 786, where the two strengths differ by 11 tons per square inch. These were evidently only first approximations, for in any equation connecting R and T,

TABLE I.—CORRELATION OF DEFLECTION RESULTS ON BARS OF INCREASING DIAMETER AND SPAN FOR B.S.S. NO. 786, GRADES 2 AND 4.

Diam. In.	Span. In.	Deflection. In.		Deflection on 18-in. Span. In.		Deflection × Diameter.	
		Grade 2.	Grade 4.	Grade 2.	Grade 4.	Grade 2.	Grade 4.
0·6	9	0·08	0·10	0·32	0·40	0·19	0·24
0·875	12	0·12	0·14	0·27	0·32	0·24	0·28
1·2	18	0·17	0·23	0·17	0·23	0·20	0·28
1·6	18	0·14	0·18	0·14	0·18	0·22	0·29
2·1	24	0·19	0·24	0·11	0·13	0·23	0·27

* Paper read at the 38th annual meeting of the Institute of British Foundrymen, held in Manchester on Saturday, July 12, 1941. Abridged.

THE "CRUSADER" CRUISER TANK.

(*For Description see Opposite Page.*)

Fig. 1.

when one is zero, the other must also be zero. The development in recent years of high-duty irons has enabled a much wider range of strengths to be charted from a large number of cases. From the transverse and tensile strengths so obtained, the curve, Fig. 3, page 125, results, and it will be seen that in the middle range it is substantially straight, and slightly curved at the upper and lower ends. This curve enables the transverse strengths to be more accurately estimated with respect to corresponding tensile strengths. The full line covers the range of strengths for which evidence is available. Figures for the tensile strengths given in the two specifications are accompanied by the transverse values deduced from this curve in Table II, herewith.

Table II.—*Transverse Values for Specified Tensile Values.*

Tensile. Tons per Square Inch. From No. 321 and No. 786.	Corresponding Transverse. Tons per Square Inch. From Fig. 3.	Transverse from B.S.S. Specifications.
9·0	19·6	17·7, 18·3, 18·9
10·0	20·7	19·6, 19·9
10·5	21·2	21·4
11·0	21·8	23·1
12·0	22·9	24·1
12·5	23·4	25·1, 23·6
13·0	24·0	24
14·0	25·1	25
15·0	26·2	25·9, 26·1
16·0	27·3	27
17·0	28·4	28
18·0	29·5	28·9, 29·1
19·0	30·6	30
20·0	31·7	31
21·0	32·8	33
22·0	34·0	33, 35
23·0	35·3	34, 37
25·0	38·3	39
26·0	40·0	41

It will be seen that the differences are small, but inconsistencies are removed. A series of values which form a continuous range for the 1·2-in. bar of tensiles at intervals of 2 tons, is given in Table III, on this page. The odd series includes four already appearing in No. 321 and No. 786, and the even series only two, marked with an asterisk. The corresponding deflections can also be accurately estimated, as indicated above. In this way, a regular range of irons could be specified, covering all reasonable requirements, giving eight materials in place of the present six. The effect is to fill the gap between Grade A and Grade 1, retaining Grades A and C. Grades 1 to 4 are virtually retained, with a grade between 3 and 4 to make a consistent series. Such a series would enable the present mixed nomenclature of letters and figures to be improved. The straight portion of the curve, Fig. 3, has an equation of approximately $R = 1{\cdot}1T + 9{\cdot}5$, or the transverse rupture stress is 1·1 times the ultimate tensile stress plus 9·5 tons. The curved portions would have equations of such a kind that it is simpler to determine R appropriate to a particular value of T or vice versa directly from the curve.

The equation could be altered to give a very different appearance without substantially altering the results. From a much more limited range of values, the author gave in 1930 the equation $T = 0{\cdot}59R - 4{,}000$, the stresses here being in pounds per square inch,* and the resulting R from a given T is not widely different in the two cases.

Table III.—*Proposed Series.*

Odd.		Even.	
Tensile. Tons per Square Inch.	Transverse. Tons per Square Inch. Fig. 3.	Tensile. Tons per Square Inch.	Transverse. Tons per Square Inch. Fig. 3.
9*	19·6	10	20·7
11*	21·8	12	22·9
13	24·0	14*	25·1
15	26·2	16	27·3
17*	28·4	18	29·5
19	30·6	20*	31·7
21	32·8	22	34·0
23*	35·3	24	36·8

One very interesting result follows from the curve, Fig. 3. It has been supposed hitherto that, as irons improve, the transverse value does not increase as rapidly as the tensile, and conversely that, in the weaker irons, the tensile is lowered relatively more than the transverse. Fig. 3 shows, through the bending of the high-duty iron end to the horizontal axis, that R increases relatively more than T. At the other end, the bend in the reverse direction shows that the view with regard to weaker irons was correct. The author is confident that, while for various reasons freak results may be recorded, as a general rule any combination of tensile and transverse figures obtained from properly tested sound bars will not lie far off the line in Fig. 3. In all cast metals, a thick section is weaker per unit area than a thin section of the same metal. One of the great advantages of high-duty irons is that they show this change much less than commoner irons, and, of course, by appropriate adjustments to composition, the difference in strength between larger and smaller castings is minimised. Even so, however, the founder is not expected to obtain the same strength in a thick as in a thin bar. It may be asked whether there is any logic in providing that the strength of a large casting in, say, Grade 2 iron, should be slightly lower than that of a smaller casting in the same iron. It may be argued that if a consumer wants 18 tons per square inch, he wants it irrespective of section, and that there would be no difficulty in supplying him with the same strength in a heavy section, even if the maker were driven to use a different mixture. This, indeed, is the solution adopted by our American friends, who, incidentally, have adopted British practice of varying test-bar size with section of casting, although they were many years ahead in the use of the round bar and of the tensile test. The quality of the various grades of cast irons specified in the United States is independent of section, although test-bar and casting are related.

There is, however, advantage to be gained by following British practice. First of all, it assists the buyer to realise that he cannot expect quite the same properties in a large section as in a smaller section, and in extreme cases he is prevented from asking for heavy castings in strengths appropriate to lighter castings. Secondly, it is the usual practice for a firm to concentrate on the production of a few types of material, and the average founder finds it inconvenient to change his practice and mixtures with each order. There is considerable practical convenience in a recognition of the fact that a foundry making a range of sizes in, for example, Grade 2 iron, will not obtain quite the same strength in the heavier castings. Taking the present standard bar sizes, it will also be found that the tensile-transverse points in Fig. 3 for the range of diameters will also lie very closely on the curve, and thus a series of values not only for each grade of iron, but also for each size of bar can be evolved, consistent in themselves and to the whole. In practice there will be about one ton per square inch difference in tensile strength between each bar and the one next to it in the series. Thus a complete range of strengths and deflections can readily be built up. Incidentally, in a series of five test bars, the diameters of four of which are expressed in tenths, the diameter of the 0·875-in. bar is unlikely to remain in eighths.

* "The Correlation of Mechanical Tests for Cast Iron." *Trans. American Foundrymen's Association*, vol. 38, pages 673–711 (1930).

THE "CRUSADER" CRUISER TANK.

FIG. 2.

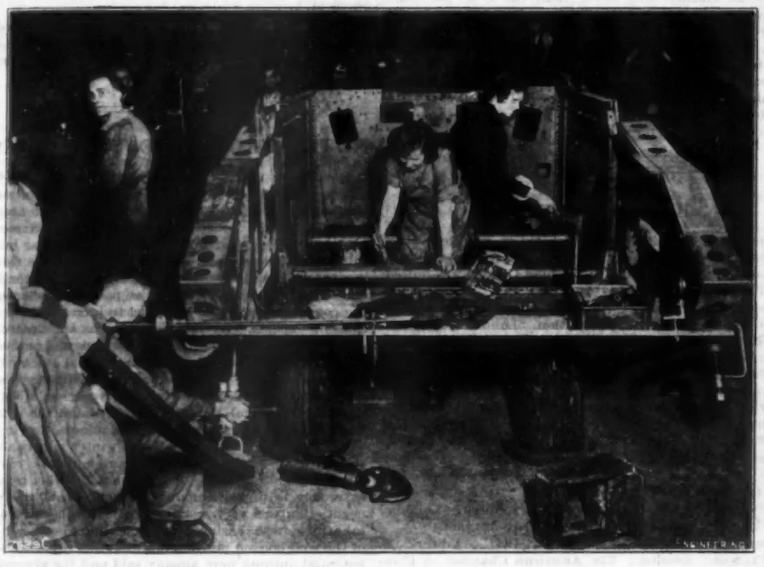


FIG. 3.

Little difficulty has arisen from the use of separately cast test-bars, the metallurgical desirability of which, compared with the cast-on bar, is now accepted. It is noteworthy that one important authority some years ago expressed its willingness, in case of dispute, to accept the identity of test-bar and casting by an analysis for either silicon or phosphorus. The sensitivity of the analytical method is greater than the difference between the test-bar and casting, unless they were poured from the same metal at the same time. Standard methods of analysis should, of course, be used. As far as the writer is aware, no case has arisen needing to be settled in this way, and the old argument that, if the inspector is not present, the bar must be cast-on to ensure identity of bar and casting has lost its force.

GIFT OF ALUMINIUM FROM THE NETHERLANDS EAST INDIES.—The people of the Netherlands East Indies have presented 200 tons of aluminium to the Ministry of Aircraft Production. The aluminium is in the form of pots and pans and utensils of all descriptions.

ADDITIONAL CLOTHES FOR MINERS RETURNING TO COLLIERIES.—Miners returning to the industry may obtain their first new outfit of pit clothing and boots coupon-free. They must, however, obtain a certificate, signed by the mine manager and countersigned by one of H.M. Inspectors of Mines, stating that the clothing is essential to the miner's work. These certificates are in all respects equivalent to coupons.

INCREASED CHARGES ON CANALS.—The Minister of War Transport has issued three Orders authorising increases in the tolls and charges lawfully levied on September 3, 1939, on certain waterways. The Orders are entitled the Calder and Hebble Navigation (Increase of Charges) Order, 1941 (S.R. & O. 1941, No. 995); the Sheffield and South Yorkshire Navigation (Increase of Charges) Order, 1941 (S.R. & O. 1941, No. 996); and the Trent Navigation and Nottingham Canal (Increase of Charges) Order, 1941 (S.R. & O. 1941, No. 997). Copies of these Orders are obtainable only from the Ministry of War Transport, Berkeley Square House, Berkeley-square, London, W.1. The price is 1*d.* net each, and the postage is 1*d.* extra.

THE "CRUSADER" TANK.

IN two recent issues of ENGINEERING we have reproduced comparative photographs of British tanks, together with such particulars as have been officially released for publication. The first article, on page 50 of the issue of July 18, dealt with the "Valentine" infantry tank, formerly known as the Mark III, and was accompanied by some illustrations of Russian tanks of broadly similar design though, it is believed, of higher speed, approximating rather to that of the older types of British cruiser tank. The more heavily protected "Matilda" type, extensively used by the British forces operating in North Africa, was the subject of the illustrations which appeared on page 70, *ante*, in the issue of July 25. The photographs reproduced on this and the opposite page, and on page 130, show another British cruiser tank, the "Crusader," under construction and carrying out demonstration exercises. Fig. 1, on the opposite page, is a three-quarter general view of the "Crusader," which is stated to have "the speed of a light car" and to be exceptionally manœuvrable. Another action photograph is reproduced in Fig. 5, on page 130. Figs. 2 and 3, on this page, show tanks of this type in course of construction, and enable some of the main features of the design to be studied more closely. Fig. 4, on page 130, is a general view of the erecting shop at a works where this class of tank is now in quantity production; and the final illustration, Fig. 6, on the same page, gives a view of one of the tracks rolled up. It will be seen that the track differs somewhat from the type used on the "Valentine" tank, the design of which was shown in comparable detail in Fig. 5, on Plate I, *ante*. In spite of its speed, which is believed to be as much as, or more than, that of any enemy tank which the "Crusader" is likely to encounter, we understand that the riding quality of the type, across country, is of an unusually high order.

THE MEASUREMENT OF FRUSTUMS.*

By PROFESSOR C. L. T. GRIFFITH.

IN excavations it may happen that there are side batters, the measuring-up of which may not be easy in ground of changing or irregular slope. The same sort of geometrical figures, pyramids and frustums are found round some concrete foundations with sloping sides, and here, if there is difficulty, it will be because the formation is not on level rock or hard earth. All quantity surveyors know how to measure a pyramid, but they usually avoid using the "prismoidal formula" for the frustums as they think it too complicated and consider that approximate methods are near enough. A long length of side slope is divided up into convenient portions, all of which, except, perhaps, a pyramid at one end, are frustums of triangular section.

Surveyors use two methods of approximating to the contents of a frustum. The first is to find the area of the middle section and assume this to be the mean section. Multiplying this by the length between the end sections, a reputed volume of the frustum is obtained. The result is always too small; so contractors' engineers, if they knew this fact, would avoid using the middle-section method of measurement. The second method is to take the mean of the areas of the two end sections and treat this mean as the true mean section. Here the result is always too large. The owner's engineer should discountenance its use. A Table follows, in which the percentage errors of the two methods are given for some values of the ratio of the area at the small end of the frustum to the area at the large end.

From the Table it will be seen that, when the area of the small end is larger than half the area of the large end, the error by either method is less than 2 per cent.; so engineers on both sides of the fence are recommended to break up irregular frustums into such

Volume of Frustums: Correction Factors.

A.	B.	C. Add Per Cent.	D. Deduct Per Cent.
0	0	33·3	33·3
0·05	0·22	13·4	19·1
0·1	0·32	9·0	14·2
0·2	0·45	4·9	8·5
0·3	0·55	2·8	5·2
0·4	0·63	1·7	3·2
0·5	0·71	1·0	1·9
0·6	0·77	0·54	1·06
0·7	0·83	0·26	0·52
0·8	0·89	0·10	0·21
0·9	0·95	0·02	0·05

* From the *Transactions of the Society of Engineers*, vol. xxxii, page 7 (Jan. to June, 1941). Abridged.

lengths that the small end of any bit is not less than half the area of the large end, or, say, three-quarters in linear dimensions, if the ends are symmetrical figures. Column A give the ratios of the areas of the small ends to the areas of the large ends. Column B gives the square roots of the figures in column A, and is the ratio of any side of the section at the small end to the corresponding side of the section at the large end, if the two ends are symmetrical figures. Column C gives the percentage to be added to the volume obtained by assuming the middle section to be the mean area. Column D gives the percentage to be deducted from the volume obtained by assuming the mean of the two end areas to be the true mean area.

As the mean of the end areas of a frustum give a result larger than the true mean cross-sectional area, and the central cross-section is smaller than the true mean area, it follows that there must be two cross-sections, exactly equidistant from the central section, the mean area of which is exactly the true mean area. Algebraical investigation shows that, if h be the perpendicular length (or height) between the two parallel ends of a frustum, the two sections looked for are situated at a distance on either side of the centre equal to h divided by the square root of 12, or $h \times 0{\cdot}2887$. Hence the distance of these two special sections from the ends is $h \times 0{\cdot}2113$. This last value is approximately $\frac{h}{5}$, and makes this new rule nearly the same as Dufton's rule for finding areas, which, the writer believes, is far more accurate (and easier to use) than any of the Simpson rules. If the cross sections, when using any method, are taken by scaling from plans and sections, this third method requires little, if any, more work than either of the two given above, and less than the work involved in using the prismoidal formula. It has the same accuracy as the prismoidal formula. It is believed that this is a new theorem in the mathematics of mensuration.

OIL-RETAINING BRONZE BEARINGS.

TIN bronzes have long held an important place among bearing-metal alloys and some years ago their sphere of usefulness was considerably widened by the application of modern powder-metallurgy methods, whereby bearings, bushes, and other components are produced by compressing the powdered alloy in dies by means of a powerful press. A valuable feature of these bearings is that they comprise about 30 per cent., by volume, of fine pores or capillary spaces which serve the useful purpose of absorbing oil. Indeed, it is stated that sufficient oil is taken up to maintain the working surface in a permanently lubricated condition throughout its working life. A wide range of these bearings is made by Messrs. Bound Brook Bearing Company, Bound Brook, New Jersey, U.S.A., and by a firm established in this country some years ago, Messrs. British Bound Brook Bearing Company, Birch-road, Witton, Birmingham, 6. Some technical details regarding the bearings, as given by the makers, are quoted in an article by Mr. W. R. Lewis, B.Sc., of the Tin Research Institute, in a recent publication of that Institute. The percentage composition of the alloy is stated to be: copper, 88·0; tin, 9·7; graphite, 1·4; and "other material," 0·9. The hardness on the Rockwell B scale, using a $\frac{1}{16}$-in. ball and 100 kg.-load, is given as 97 to 100. (This is equivalent to about 200-240 Standard Brinell numbers.) The oil content by volume is claimed to be from 23 per cent. to 30 per cent., the specific gravity from 5·8 to 6·5, and the crushing strength approximately 31·25 tons per square inch.

The bearings are impregnated with oil by immersion before dispatch, but it is advisable to dip them into a good grade of medium heavy oil before placing them in service so that there is sufficient oil to fill the space between the bearing and the shaft at the outset. Porous bronze bearings are mainly employed in fractional horse-power electric motors, vacuum-sweeper mechanisms, sewing machines, fans, cycle dynamos, hoists, electric drills and in places where oiling is difficult or may be neglected, such as the control levers and pedals of aircraft and motor cars, compressors, switchgear and conveyor rolls. It is claimed that a vacuum-cleaner motor having a shaft rotating at 18,000 r.p.m., ran 300 hours without a sign of wear, and that a $\frac{1}{2}$ horse-power motor, in a continuous run of over 1,000 million revolutions, lasting well over a year, also showed no signs of wear and consumed less than 10 grammes of oil. Another remarkable example quoted by the British Bound Brook Bearing Company concerns a plant of 176 spinning machines, each having 200 bearings and shafts running at speeds ranging from 3,500 r.p.m. to 10,000 r.p.m., from Monday, day and night, to Saturday. The machines are stated to have run for four years with practically no attention.

BRITISH STANDARD SPECIFICATIONS.

THE following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, and, unless otherwise stated, the price is 2*s.* net, or 2*s.* 3*d.* including postage.

Capacitors for Radio Receivers.—Some time ago the Radio Manufacturers Association prepared two specifications for capacitors, one dealing with the rating and dimensions of paper and electrolytic capacitors and the other with the colour coding of capacitors. These two specifications have now been combined into a single publication and issued by the British Standards Institution as War-Emergency Standard No. 271-1941. This, in effect, is a revision of the specification issued in 1926 for fixed capacities for radio reception purposes and its object is to provide a limited range of sizes and types of condensers to be manufactured in war time. It is considered that this restricted range will meet all the normal requirements of the industry under present conditions.

High-Tensile Structural Steel for Bridges, etc.—All high-tensile structural steel has been covered largely by the requirements of specification No. 548 for high-tensile structural steel for bridges, etc., but the British Standards Institution has just issued a War-Emergency Specification (No. 968-1941) which provides for a special quality of steel suitable for welding purposes. Recent investigations made by the Institute of Welding have shown that unless special precautions be taken when welding high-tensile steel, difficulties may arise owing to hardening at the weld boundaries. With a given set of welding factors the degree of this hardening may be reduced by lowering the carbon content of the steels, and as a result, special welding quality high-tensile steels are now available having maximum carbon contents considerably lower than the 0·30 per cent. which is allowed by specification No. 548, and with correspondingly improved weldability. The new standard relates to steels of this type in which the carbon content is limited to a maximum of 0·23 per cent. These are designated "high-tensile (fusion-welding quality) steels," abbreviated to H.T.W. steels. The material dealt with is suitable for fusion welding but is not suitable for forge or smith welding.

BOOKS RECEIVED.

Materials of Supply. Their Distribution and Production. By S. F. MERSEREAU. Revised and enlarged edition. London: McGraw-Hill Publishing Company, Limited. [Price 14*s.*]

Drainage and Flood-Control Engineering. By PROFESSOR G. W. PICKELS. Second edition. London: McGraw-Hill Publishing Company, Limited. [Price 28*s.*]

Applied Heat Transmission. By PROFESSOR H. J. STOEVER. London: McGraw-Hill Publishing Company, Limited. [Price 17*s.* 6*d.*]

India. Central Board of Irrigation. Publication No. 5. Revised edition. *Glossary of Technical and Vernacular Terms in Connection with Irrigation in India, Together with Standard Notations.* Simla: Offices of the Board.

Air Navigation. Based on Principles and Methods Applicable also to Sea Navigation. By F. G. BROWN. Sydney: Angus and Robertson Limited. London: Chapman and Hall, Limited. [Price 32*s.* net.]

The Anglo-American Year Book, 1941. Editor: E. CLUNAS. London: The American Chamber of Commerce in London, Bush House, Aldwych, W.C.2. [Price 15*s.* net.]

Fire Protection and A.R.P. Year Book, 1941-1942. London: Lomax, Erskine and Company, Limited, Aldwych House, Aldwych, W.C.2. [Price 7*s.* 6*d.* net.]

The Institution of Railway Signal Engineers. Proceedings, 1940. (*September*, 1939, *to December*, 1940). Reading: Greenslade and Company (Reading), Limited. [Price 7*s.* 6*d.* to Non-Members.]

The Oil Engine Manual. Second edition. By D. S. D. WILLIAMS and J. M. SMITH. Published for Temple Press Limited. London: The English Universities Press Limited, Warwick-square, E.C.4. [Price 7*s.* 6*d.* net.]

Department of Scientific and Industrial Research. Index to the Literature of Food Investigation. Volume 12. No. 2, *September*, 1940. No. 3, *December*, 1940. Compiled by AGNES E. GLENNIE. London: H.M. Stationery Office. [Price 4*s.* 6*d.* net each.]

The Journal of the Institute of Metals. Volume LXVI, 1940. Edited by N. B. VAUGHAN. London: Offices of the Institute, 4, Grosvenor-gardens, Westminster, S.W.1.

The Institute of Metals. Metallurgical Abstracts (General and Non-Ferrous) New Series. Volume 7. 1940. Edited by N. B. VAUGHAN. London: Offices of the Institute, 4, Grosvenor-gardens, Westminster, S.W.1.

PERSONAL.

THE Minister of Aircraft Production has appointed MR. G. W. LACEY to the position of Light Metals Controller. He will be responsible for controlling aluminium, magnesium, silicon and the light alloys. Mr. Lacey succeeds MR. G. CUNLIFFE, who was Aluminium and Silicon Controller and MR. G. C. USHER, who was Magnesium and Light Alloys Controller.

MR. E. H. COOPER, chairman of Messrs. Gillette Industries, Limited, London, has been appointed war-production adviser, and MR. W. GRANT, Parliamentary Secretary to the Ministry of Labour, labour adviser to the Ministry of Commerce, Government of Northern Ireland. As stated on page 89, *ante*, the Ministry of Commerce has taken over full responsibility for war production in Northern Ireland.

As from August 1, MR. H. H. SWIFT, assistant electrical engineer, chief electrical engineer's department, London and North Eastern Railway, is to be styled assistant chief electrical engineer. Other changes of title affect the three assistant electrical engineers, namely, MR. B. JAMES, of the Southern Area; MR. H. W. GREEN, of the North-Eastern Area; and MR. J. R. SHEWAN, of the Scottish Area. The new styles are electrical engineer (Southern Area), (North-Eastern Area), and (Scottish Area) respectively.

MR. A. KIRKWOOD DODDS, a director of Messrs. L. G. Mouchel and Partners, Limited, and a founder member of the Reinforced Concrete Association, has succeeded MR. DOUGLAS H. GREEN as chairman of the Council of the Association.

PROFESSOR A. F. BURSTALL, who occupies the Chair of Engineering at the University of Melbourne, has been appointed a member of the State Electricity Commission of Victoria, Australia.

MR. ARTHUR EDWARD MORRISON has succeeded the late MR. FRANK MOORE as managing director of Messrs. Moore and Wright (Sheffield), Limited, Trafalgar-street, Sheffield, 1.

MR. FRANK H. WHYSALL, M.I.E.E., who has served as City Electrical Engineer and general manager, Belfast Corporation Electric Supply, since 1927, is to retire on March 31, 1942.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—The problem of increasing the output in this district has been brought again to the fore by the debate on the coal position recently held in the House of Commons. Of particular interest to South Wales was the announcement by the Government that, in order to free further supplies for the home market and to prevent as far as possible a shortage in the coming winter, they intended to increase the restrictions on exports. By this means it was anticipated that a large quantity of Welsh dry steam coals and anthracites would be made available. It was pointed out by Welsh Members during the debate that the difficulty was not one of transport, as was the case last year, but of shortage of coal. The local Members also repeated the demand, frequently made by the South Wales miners, that in order to prevent a shortage of coal next winter miners already called-up for service in the Forces should be released. Meanwhile, although the demand on the market remained extremely brisk, the amount of business that was under negotiation was very restricted. Salesmen could undertake little fresh business for some time to come, in view of the well booked position of most collieries. As a rule, potential outputs were already sold and the general tone was consequently very firm. Best large coals were in steady demand but, with outputs earmarked for contract deliveries, the amount of business that could be arranged was limited. The sized sorts were very sparingly available and a strong tone ruled for the bituminous small kinds which were in brisk request and any odd lots that sellers had to offer were readily taken up. Inferior dry steam smalls received little attention and were dull. Cokes were busy, but patent fuel continued quiet.

The Iron and Steel Trade.—Activities in the iron and steel and allied trades of South Wales and Monmouthshire were well maintained during the past week. Most works were engaged almost to full capacity in dealing with orders already in hand.

RAILWAYS IN SWEDEN.—Upwards of 3,800 km. of the 9,700 km. of State-owned railways in Sweden have been electrified, and that these electrified lines are the most important is shown by the fact that they carry about 90 per cent. of the entire passenger and goods traffic dealt with by the Swedish State Railways. Nearly 7,000 km. of line in Sweden are privately owned and, of these, about 700 miles are electrically operated. In order to economise coal, steam locomotives, as far as possible, are utilising wood fuel.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Sheffield's industrial holiday being over, the works are now operating at full capacity. The plants have all been overhauled and a record-breaking run until Christmas is in prospect at many concerns. The demand for steel and steel products for Government use continues to grow, and it is therefore not surprising that manufacturers have not been able to meet, in full, the requirements of commercial customers. Difficulty also exists in coping with export needs. In view of the fact that Russia is now an Ally some manufacturers who formerly did a considerable trade with that country in various products, including saws, shovels, files, tools, and certain types of agricultural equipment, are wondering whether trade between the two countries will be resumed. Argentina is inquiring for electric motors; Canada for small hand tools; Turkey for corrugated sheeting, and machinery for the construction of roads and tunnels, air-conditioning plant, compressors, pneumatic tools, traction equipment, and small engines for operating cement and concrete mixers. Larger outputs of raw and semi-finished steels are being produced and Sheffield's imports of pig iron and hematites are increasing. Basic steel is in strong demand, and the call for acid steel is growing. The scrap position is satisfactory. In some districts furnaces could have taken larger quantities of basic-steel scrap than were available at the time, but this was not general, and is not likely to recur. There is a brisk market in high-efficiency and alloy steels, and production is being steadily increased at the expense of some steels which are in smaller demand. The heavy machinery and engineering branches are operating at full capacity, and active conditions are general in the tool-making branches.

South Yorkshire Coal Trade.—The coal position generally had undergone little change. Efforts are being made at many pits to increase outputs, and good results are being obtained. All types of industrial coal are in strong demand; steams are moving freely, and there is an improved call for locomotive coal. The house coal market is satisfactory, and larger quantities are available for distribution. Foundry and furnace cokes are steady, and gas coke is an active line. The export position shows no change.

HERBERT AKROYD STUART AWARD.—As a result of the 1939/41 competition for the Herbert Akroyd Stuart Award, the Council of the Institute of Marine Engineers has conferred this award upon Mr. C. C. Pounder, member, for his paper entitled "Some Recent Diesel Installations and their Characteristics," published in the Institute's *Transactions* of February, 1939.

THE NICKEL BULLETIN.—The current issue of *The Nickel Bulletin* contains well-written abstracts of recent literature on the welding of nickel and high-nickel alloys, the design of pressure vessels, bright nickel plating, the influence of cold work on the electrical resistance of nickel-copper alloys, and other matters of interest to engineers and metallurgists. Copies of the *Bulletin* may be obtained gratis on application to the Mond Nickel Company, Limited, Grosvenor House, Park Lane, London, W.1.

ARTIFICIAL-DAYLIGHT LAMP.—An interesting application of fluorescent tubular lamps has recently been made by Messrs. Crompton Parkinson, Limited, of Electra House, Victoria Embankment, W.C.2. A chemical process in a Government factory involves the addition of acids to a liquid at controlled stages, which are determined by changes of colour. The operation is a delicate one and normally was carried out only under favourable daylight conditions. As, however, the fluorescent tubular lamp gives an illumination closely resembling daylight, and more constant in character, they were introduced for the work. Investigation showed that an illumination of 120 ft. to 150 ft. candles over a working area of 6 ft. by 4 ft. 6 in. was necessary. This was provided by four 80-watt Crompta tubular lamps provided with a chromium-plated brass reflector and mounted sufficiently high to be out of the line of direct vision.

WORKS OF ALUMINUM COMPANY OF AMERICA.—The capacity of the works of the Aluminum Company of America, at Vancouver, Washington, U.S.A., has recently been increased by the addition of a fifth production unit, and the plant is now capable of producing 67,000 tons of aluminium per annum. Power is supplied by the Bonneville plant on the Columbia River, which has recently been described in our columns. The first aluminium-production unit was started up in September, 1940, and second, third and fourth units were added in December, 1940, and in March and April, 1941. The capacity of the plant at the present time is stated to be larger than the output of the United States, as a whole, during the war of 1914-18. Furthermore, the present output, we are informed, is only 20 per cent. of the quantity of aluminium which it is intended to produce in 1942. The present staff and workpeople number 800.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The usual customers continue to experience difficulty in obtaining iron and steel for ordinary industrial requirements, but firms engaged directly in the production of commodities for Government purposes are receiving regular and adequate supplies. Under normal conditions business is expected to be quiet at this time of the year and there is some reduction in the demand for certain descriptions of material, but the call for most products is undiminished. Buying ahead, however, is on a reduced scale, which may be attributed to the realisation that under the control of distribution regulations, extensive forward purchasing is not essential. Manufacturers are not permitted to accept orders except under delivery licences and these are granted with caution.

Cleveland Iron Trade.—Increasing quantities of pig iron are required for foundry work, notwithstanding the extensive use of scrap, but the supply is ample although the make of Cleveland brands is still intermittent and small. There is no indication of any preparation for an early increase in output, but deliveries from the Midlands and other iron producing centres are more than sufficient for current needs. Business is still being done, in most cases, directly between producers and consumer, but merchants are handling rather more tonnage than has been the case for some time. The official values of Cleveland pig remain at the level of No. 3 grade of iron at 128*s.* delivered in the Middlesbrough district.

Basic Iron.—The whole of the heavy basic-iron production is retained for use at makers' adjacent steelworks. With no tonnage on the market the fixed price of 120*s.* 6*d.* is nominal.

Hematite.—There is still a shortage of hematite although the position is easier owing to the increasing use of substitute iron and steel scrap. The demand, however, remains in excess of the supply and conditions still prevent an enlargement of the output. The limited tonnage distributable is carefully allocated. The recognised market quotations are ruled by No. 1 description of hematite at 138*s.* 6*d.*, delivered to North of England buyers.

Foreign Ore.—The dependence on supplies of foreign ore has been greatly reduced by the use of native ironstone, wherever possible, and cargoes arriving from overseas are sufficient for most requirements.

Blast-Furnace Coke.—Market transactions in Durham blast-furnace coke are few though the supply is plentiful and the local consumption heavy. Sellers have large holdings, but are not inclined to add to their extensive commitments, and North East Coast users have carried their requirements as far ahead as they consider advisable. The market prices are based on good medium qualities at 36*s.* 9*d.*

Manufactured Iron and Steel.—Deliveries of semi-finished and finished iron and steel are being maintained on a satisfactory scale. The aggregate output is exceptionally heavy and imports from the United States can be regulated according to requirements. Re-rollers have substantial stocks of semies. The output of manufactured iron is large and producers have good orders for heavy descriptions of material, but could handle more light work than they have on hand at present. Sheets and structural steel are in less urgent request than has been the case for some time, but delivery demands for shipbuilding material and requisites for engineering establishments is unabated, and the production of special alloy steels is expanding rapidly. Any railway material available is readily taken up.

Scrap.—There is no lack of light iron and steel scrap, but the supply of heavy grades does not fully meet requirements. Machinery metal, heavy cast iron and swarf steel, are in demand.

THE CENTRAL REGISTER.—According to the Parliamentary correspondent of *The Times*, 4,065 persons whose names are on the Central Register have been appointed to posts in Government Departments in the first six months of the present year.

THE LATE MR. A. CHAMBERLAIN.—We regret to record the death of Mr. Arthur Chamberlain, which occurred suddenly at his home, Rackenford Manor, Tiverton, Devon, on August 7. Mr. Chamberlain, who was 61 years of age, was a cousin of the late Prime Minister. In 1918 he joined the board of Messrs. The General Electric Company, Limited, having been associated with the firm of Messrs. Chamberlain and Hookham, Limited, Birmingham, which was absorbed by the General Electric Company at that time. Mr. Chamberlain was also chairman of Messrs. Tube Investments, Limited, Paddock Works, Oldbury, Worcestershire, and a director of a number of other industrial concerns.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF PRODUCTION ENGINEERS.—*Manchester Section:* Monday, August 18, 1941, 7.30 p.m., The College of Technology, Manchester. Joint Meeting with THE MANCHESTER ASSOCIATION OF ENGINEERS. "Psychological Factors in Accident Causation," by Mr. C. A. Oakley.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—Tuesday, August 19, 6.30 p.m., The Lighting Service Bureau, 2, Savoy-hill, Strand, W.C.2. Illustrated Lecture: "Electricity in the Modern Film Studio," by Mr. F. V. Hauser.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—There has been little change in the Scottish steel trade during the past week, but new business has been somewhat quieter. Specifications against contracts have, however, been coming in regularly, and are being dealt with promptly as production continues on a large scale. Ship and boiler plates are in strong demand and there is also a pressing demand for special high-grade steels. In the black steel-sheet trade the position shows no change, and although order books represent a considerable amount of work on hand, new business is slow in coming forward. The demand for sheets on Government account is steady, but the current production is sufficient to permit immediate deliveries of material urgently required. The following are the market quotations:—Boiler plates, 17*l.* 12*s.* 6*d.* per ton; ship plates, 16*l.* 3*s.* per ton; sections, 15*l.* 8*s.*; medium plates, ¼ in. and thicker, rolled in sheet mills, 21*l.* 15*s.* per ton; black-steel sheets, No. 24 gauge, 22*l.* 15*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, 26*l.* 2*s.* 6*d.* per ton, all for home delivery.

Malleable-Iron Trade.—There is an easier tone in the malleable-iron trade of the West of Scotland this week, but a satisfactory amount of business still remains on the order books. Recent deliveries of scrap have been rather limited and a larger tonnage of pig-iron has had to be used with the result that production costs are higher. The re-rollers of steel bars report no change in conditions and are able to meet their booked obligations with promptness and can also give early deliveries of any new orders received. Supplies of semies are ample for all requirements. Prices are steady and are as follows:—Crown bars, 15*l.* 12*s.* 6*d.* per ton; No. 3 bars, 13*l.* 12*s.* 6*d.* per ton; No. 4 bars, 13*l.* 17*s.* 6*d.* per ton; and re-rolled steel bars, 17*l.* 15*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—Active conditions continue in the Scottish pig-iron trade. There is a strong demand for hematite iron by the steel makers, and foundry grades are moving more freely. To-day's market quotations are as follows:—Hematite, 6*l.* 18*s.* 6*d.* per ton, and basic iron, 6*l.* 0*s.* 6*d.* per ton, both delivered at the steel works; foundry iron No. 1, 6*l.* 5*s.* 6*d.* per ton, and No. 3, 6*l.* 3*s.* per ton, both on trucks at makers' yards.

INSTITUTION OF FACTORY MANAGERS.—The Council of the Institution of Factory Managers awards an annual silver medal and commendation in honour of its first President, Sir Henry Fildes, M.P., J.P. The 1941 medal and commendation will be awarded for the best essays on "Factory Welfare." The competition is open to all ages and ranks, and entries will be judged in two groups. In the senior group are entrants aged 27 years, or over, on January 1, 1941; and, in the junior group, those below that age. Entrants in the senior group compete for the medal and those in the junior group for the commendation. Essays should be type-written and not exceed 5,000 words, and should be addressed, by registered post and before September 1, to the Secretary of the Institution, Ashton New Hall, Ashton-on-Mersey, Cheshire.

SWEDISH WOOD-CONSUMING GAS PRODUCER.—A new type of gas producer for use in steelworks and industrial plants is being manufactured by the Swedish firm, Messrs. A/B Svenska Järnvägsverkstäderna. The designer is Mr. Axel Ohlsson and it is claimed that any solid fuel, including wood and peat, may be employed without making any changes in the equipment. The producer, to which the name "Parca semi-gas generator" has been given, is claimed to be very economical in use. In a practical test in a Swedish steelworks, a temperature of 1,340 deg. C. is stated to have been attained when the producer was used in conjunction with a reheating furnace. The fuel employed was wood, and the steel under treatment was soaked at a temperature of 1,200 deg. C. The new producer has also been adapted for service in water central-heating plants.

THE "CRUSADER" CRUISER TANK.

(*For Description see page* 127).

Fig. 4.

Fig. 5.

Fig. 6.

ENGINEERING.

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We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and other publications bearing somewhat similar titles.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The Proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

All accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

TEMPORARY ADDRESS.

For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.

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ENGINEERING

FRIDAY, AUGUST 15, 1941.

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THE WAGE CURVE.

REPLYING to a suggestion made in the House of Commons on August 7, that a minimum wage of 3*l.* a week should be fixed for agricultural workers, the Minister of Agriculture (Mr. R. S. Hudson) said that, as a result of increases in the statutory minimum in 14 counties, there were very few farm workers who were not earning 3*l.* a week, during the summer months at all events. When, last year, they had put forward a claim for a national minimum, the Agricultural Wages Board proposed a figure of 42*s.*; but he and the Minister of Labour, in view of the fact that the men were tied to the industry, suggested the figure of 48*s.* He had hoped in this way to do something towards lessening the gap between the earnings of agricultural and other workers. This object was achieved for only a short time, because of other classes of labour applying for, and receiving, further advances. In May of this year farm workers, as a body, put forward a claim for a 3*l.* minimum. He had refused to meet the farmers' organisation in connection with the matter as it fell within the ambit of the Agricultural Wages Board, which had been deliberately set up as a buffer between the State and the county committees. It would be most improper for him to exercise any influence on the Board, which would review the matter again in November. It had virtually promised to grant an increase of wages.

This Parliamentary reply epitomises the whole present wage situation. Claims for increases are based both on rises in the cost of living and on comparisons drawn with wages paid in other industries or for other classes of work. In the debate on production in July, Sir John Wardlaw-Milne quoted a case of a number of women who demanded to be transferred to another department of the factory in which they were working. Asked why, they said, "Because over there they are earning double our pay and it is work we can do as easily as our own." This contention was correct. In the same debate, Sir Adam Maitland instanced a case of a Government factory in which 50 men, whose services could no longer be utilised, were asked to go to another Government factory. They refused because the rate of wages at the first factory was higher than they would have got at the other. In neither of these cases can any reasonable objection be taken to the action of the workpeople. Like anyone else, they were attracted by the better-paid jobs.

The serious rise in the general level of wages is not due only to this competitive activity between different classes of labour. Probably to a greater extent, it results from an apparent general acceptance of the idea that the curve of wages should follow that of the cost of living. In September, 1939, the cost-of-living figure was 55 points above that of July, 1914. In January, 1940, it was 74 points above; in January, 1941, 96 points; and in June, 1941, 100 points. No statistics are available covering all wages, but, certainly in some of the more important industries, the wage curve has probably risen at a steeper angle than the cost-of-living curve, and now lies above it. We do not know if the present Government would admit acceptance of the proposition that wage increases should not fall behind cost-of-living increases. They are attempting to control the latter by subsidising bread and other important foods, and in this way are doing something to influence wages. These activities may be directed to easing the situation of the poorer members of the population, but in fact their influence extends to all. Their effect on those drawing the inflated wages which are now being paid in some industries is, essentially, a further increase in their wages, though this may not be directly apparent to the individual. So far as the financial state of the country is concerned, it makes no difference whether the money is spent in increasing wages or as a potato subsidy.

Writing on this subject in our issue of January 26, 1940, we pointed out that, in the first eleven months of 1939, increases aggregating 650,000*l.* took place in the wages of 3,700,000 workpeople. In November of that year, an increase of 350,000*l.* took place in the wages of 1,947,000. The curve represented by these figures has not tended to fall; on the contrary, its slope every week becomes more dangerous. In the first half of 1940, 6,600,000 workpeople received increases aggregating 1,400,000*l.*; the corresponding figure for the first six months of this year was 1,300,000*l.* In July alone, an increase of 300,000*l.* took place in the wages of 1,925,000 workpeople. The Government have frequently made it clear that they do not view the financial condition of the country with equanimity, and they have recently formally stated their position in a White Paper entitled *Price Stabilisation and Industrial Policy*. This points out that there is a greatly reduced supply of consumption goods and that increase in wages will not make more goods available. If the matter is left to adjust itself, it will simply increase prices, which would bear hardly on the poor and on those with fixed incomes. It was estimated that, in 1941–2, on the basis of conditions ruling before the last Budget, the total incomes of the population would amount to a sum of 500*l.* millions in excess of the value of goods available for purchase. As the effect of this excess of purchasing power could only be to increase prices, and would automatically be followed by demands for increased wages, leading in turn to further price increases (the first stages of inflation), severe additional direct taxation had been imposed, food and clothing rationed, and subsidies introduced to prevent rises in the cost of foods. This latter process was to be extended to coal, gas, electricity and other services. Unless the extra taxation is sufficient to absorb the whole of the 500*l.* millions surplus there will be a balance left in hand which, presumably, the Government hope will mainly be conserved as savings and investments in national war securities.

Although the broad lines of this policy will be generally accepted as sound, this does not indicate a belief that it presents an adequate solution of the problem which has to be faced. Proceeding to deal with the wages question, the White Paper states that the policy of the Government was to avoid modification of the machinery for wage negotiations, which were to be left to existing joint voluntary machinery. It was stated that this procedure had operated successfully since the outbreak of war and that increases in wage-rates had been reasonable. If this is the case, it may be asked what all the argument is about and why this leaflet issues the warning that the policy of price stabilisation will be made impossible unless wage increases are prevented or at least kept within small dimensions.

There is much to be said for leaving wage negotia-

tions in the hands of the various bodies which have dealt with them in the past. They have the necessary machinery and are handling familiar problems. In general, also, they are trusted by the workpeople. The Government may claim that their policy has been successful and that the country has shouldered its heavy industrial load with very few labour troubles. From the Government point of view, the procedure also marks the easiest path; the wage boards are a comfortable buffer. Easy paths, however, frequently lead downhill. When Mr. Hudson refuses to take any part in negotiations for increased farm wages, he is acting in line with Government policy, but is not necessarily assisting the Chancellor of the Exchequer in his fight against inflation.

In adopting their present policy of non-interference, the Government have departed from their own declared intentions. On May 22, 1940, the Lord Privy Seal stated in the House of Commons that "the Minister of Labour will be given the power to direct any person to perform any services required of him . . . The Minister will be able to prescribe the terms of remuneration, the hours of labour and conditions of service." This can only mean that the Minister of Labour proposed to keep some sort of control over wage rates. Although the present declared policy of the Government is apparently that he shall do nothing of the kind, it is evident from Mr. Hudson's remarks that in the case of farm workers he interfered in favour of increasing wages. Whether there is any record of similar activity in the opposite direction we do not know.

In general, wage negotiations must continue to be carried out by the bodies appointed in the past especially for that purpose. To turn the matter over to an entirely new department of the Ministry of Labour would be expensive, would engender delay and dissatisfaction, and might possibly lead to breakdown in the whole machinery. This, however, is no reason why the Minister of Labour should not act a little more in accord with Mr. Attlee's declaration of May, 1940, nor is it any reason why the Government should not settle on the general lines of a wages policy. They are the only body in a position to exercise some sort of control over the whole field. The duty of Wages Boards are to consider the interest of the particular trades with which they are concerned. No doubt good cases have been made out for many of the advances which have been granted and the reactions of an award on other industries have lain outside the terms of reference of the Board concerned. Central authority, however, responsible to the country as a whole, could bring appropriate pressure to bear to restrain individual industries from introducing extravagant demands which in due course would lead to corresponding claims by other industries, followed again by new claims by the first, and so on down the inflationary slope.

It is not suggested that the Government could introduce uniform wages throughout all industry. A farm hand may well be a more skilled man than a capstan operator on piece work, but he is not, under the present constitution of affairs, likely to get equal wages, calculated on a purely monetary basis. This qualification is necessary, because there are compensatory features about a countryman's employment which make it difficult to assess his real wages on equal terms with those of the townsman. There are, and will remain, many overpaid jobs in mass-production manufacture. There are more of these now than in normal times. Some types of work, such as internal-combustion engine manufacture, have a long tradition of piece-work price-fixing; others, such as the construction of aeroplane frames, have no such tradition. It is very possible that some of the rates fixed for new repetition operations are too high—rate-fixing is a thankless job at best. Nothing can be done with these now except by change of method. These special cases, however, are no reason why the Minister of Labour should not exercise a general wage control and do something towards easing the present alarming slope of the wage curve. As the Minister of Agriculture admits that he and the Minister of Labour have already interfered in one case, there is evidently no constitutional objection to the exercise of ministerial control.

ROAD-TRAFFIC COMPUTATIONS.

In April, 1937, the Federal Works Agency, Public Roads Administration of the United States, presented a report on the cost and feasibility of constructing a system of transcontinental arterial roads in that country. The conclusions embodied in the report rested on the assumption that, by the year 1960, the figures for motor-vehicle traffic would be doubled. Based on considerations of population growth and comparisons of American traffic conditions, the Highway Development Survey, 1937 (Greater London), conveniently known as the Bressey Report, estimated a four-fold increase in road traffic by 1951. Forecasts of this kind are necessarily subject to a considerable margin of error. The statistics on which they are based contain too many unknowns for close actuarial computation, and the present state of world affairs has introduced a disturbing factor which the compilers of neither report can have taken into account. That one estimated rate of increase was more than double the other is sufficiently explained by the fact that the American report concerned the country as a whole, while the other was confined to the London area; also, as the number of motor vehicles per head of the population in the United States is at least four times that in Great Britain, we are at present much farther from the point at which the curve of increase will tend to turn to the horizontal.

It would be neither profitable nor even possible to estimate the effect of the war on road-traffic growth. What is clear, however, is that allowance for it must form an important item in planning for the future. It is the fashion at the moment to talk of the period after the war as an entirely new era and apparently to envisage the rebuilding of, say, a quarter of London. How the nation is to pay for the revolutionary developments so freely postulated, is not stated. Clearly the destruction which some towns and cities have suffered should, as far as possible, be turned to account and the setting up of bodies, at this early stage, to consider future lay-out is good statesmanship. Vague and magniloquent talk about a "New Age," apparently to be blessed with a bottomless purse, is, however, of no service; plans, to be useful, must be based on what is economically and socially reasonable. No doubt over-coloured prophecies about a new world are a reaction from present stress, but we were treated to the same sort of thing twenty-two years ago and it will help the future better if we base our proposals on something more solid than unsubstantial enthusiasm.

Any projected new or widened roads should obviously be planned in terms of the traffic they may be expected to have to carry at the end of some reasonably long period. The estimate of that traffic is difficult and it will be well to err on the safe side. Sir Charles Bressey's four-fold increase may well be accepted as a working figure, not necessarily for individual roads, but for a traffic district. Agreement about a future maximum traffic figure, however, does not automatically determine road width. It is difficult, for instance, to estimate what proportion of the traffic of a district will use a particular road. It is stated in the American report that 90 per cent. of traffic on main highways near cities is bound to and from the cities themselves, so that a by-pass constructed around a town may do little to relieve congestion in it. It is possible that this statement, based on conditions in the United States, where large towns are generally far apart, may not be applicable to this country; it is difficult to think, for instance, that the by-pass round the north of Oxford has not relieved the town from much through traffic to South Wales and the West.

Although estimates of future traffic must always be subject to a wide tolerance, such estimates must, none the less, be made as a basis for new road plans. The assumption of some figure does at once, however, determine the width of road required. The Federal Works Agency report, referring to superhighways, or what we would call arterial roads, states that 400 vehicles per hour, divided equally in both directions, is a maximum which may safely be carried over a two-lane road without inconvenience. This figure presumably refers to vehicles travelling at a fairly high speed on the open road, and as is probably generally known, maximum road speed does not give maximum road capacity. The estimate of 400 may be compared with some figures given by Mr. A. J. H. Clayton in a paper entitled "Road Traffic Calculations," read at a meeting of the Road Engineering Section of the Institution of Civil Engineers in April. He stated that a peak amounting to 989 vehicles per hour per traffic lane had been recorded on the Victoria Embankment at Northumberland Avenue and that, at times, more than 1,000 vehicles per hour leave the narrow gateway at Hyde Park Corner. He did not add, however, that these numbers were handled by the roads "without inconvenience," which is one of the postulates on which the American figure is based.

The effect of local conditions on road capacity, and, incidentally, the difficulty of determining the best road width for a stated traffic, were illustrated by some other figures given by Mr. Clayton. He said that the peak figure for the Trafalgar-square end of Whitehall was 550 vehicles per hour per traffic lane, and that at this density the road was working to the limit of its capacity. In Broad Sanctuary, at Parliament-square, however, at practically the same density (540 vehicles per hour per traffic lane) the road presented every appearance of having a wide margin of capacity. The difference observed was presumably due to the variations in the speed and composition of the traffic, and hold-ups at intersections. A control point, such as that at the top of Whitehall, affects the road capacity for a considerable distance behind it. The normal saturation density for the type of traffic using Whitehall was 1,500 vehicles per hour per traffic lane, and the observed figure of 550 which appeared to represent the maximum capacity was imposed by the control points.

Normal saturation density corresponded to the condition when vehicles were running at a steady rate as close together as possible, and could be determined by direct observation. A density of 2,000 vehicles per hour had been observed on the London-Portsmouth road on the evening of August Bank Holiday, 1939, and on a single lane on the Croydon By-pass, caused by a temporary bottleneck, a figure of 3,600 vehicles per hour, over periods of about 10 seconds' duration, had been observed. This latter condition, however, appeared to be very unsafe. As a result of general observations, Mr. Clayton placed the saturation density, for town conditions, at from 1,200 to 1,800 vehicles per hour. The delay factor which, in the case of Whitehall, reduced the figure to 550, was the sum of the effective running periods in any interval divided by the total time. The effective running time was the "go" period less an allowance for starting up, which experience showed could be taken at 6 seconds. In the case of Whitehall, this delay factor was 0·366, which, divided into the observed figure of 550, gave a saturation density of 1,500.

This calculation well illustrates the delay caused by traffic controls and accentuates the desirability of reducing their number as far as possible. Clearly, they must remain an essential feature of town-traffic control, but in many cases it is possible that destruction already sustained may be turned to advantage by the introduction of roundabout. In a comparison between a light-controlled intersection and a small roundabout, Mr. Clayton calculated the vehicles per hour able to pass through the intersection as 1,930. The corresponding figure for the roundabout, however, was 3,850. This comparison must be used with discretion, since, if the roads were doubled in width, the light-intersection would have double the capacity, but the roundabout, assuming its dimensions unaltered, would have its capacity unaffected. As Mr. W. F. Adams pointed out in the discussion of Mr. Clayton's paper, this argument only applied to a roundabout which was not large enough to pass all the traffic which could enter from contributory streets. As, however, the dimensions of both roundabouts and streets will continue to be limited by pre-existing conditions, the desirability of introducing roundabouts where possible may well be kept in mind by town-planning authorities.

NOTES.

TRAINING FOR ENGINEERING OPERATIVES.

THE rapid expansion of munitions manufacture and the bringing into production of the new Government factories have long ago exhausted the reserves of skilled engineering operatives, and any further increases in their numbers can only be obtained by up-grading those of somewhat less skill, but who possess sufficient experience to justify training for more responsible work. In other words, employers who require more skilled labour must look for it primarily among their existing personnel. To assist them in doing so, arrangements are being made by the Ministry of Labour and National Service to provide higher-grade courses at technical colleges, Government training centres, and in industrial establishments where the necessary equipment and instructors are available. Courses are already in operation to train employers' own operatives as setters, tool-room hands, and other skilled grades. The instruction is given by competent craftsmen who have up-to-date experience in industry and have shown themselves able to impart it. The time that they spend in this way may represent, at first, a temporary loss of output due to their withdrawal from active production, but it is realised that this loss will be more than recouped in the long run. The training is planned on practical lines and the courses, which vary in length according to the type of instruction given, but normally last a few weeks, are designed to fit a man for higher-grade work in the shortest possible time. The man who enters for such a course remains on his employer's pay-roll and receives his wages in the ordinary way during training; but no fee is required of the employer or employee for the course, and when the man has completed it, he returns to his original firm. If, for the purpose of training, the employee has to move to another district, his fare is paid, and he is eligible for lodging allowances on the same terms as transferred war workers. If it is necessary to provide substitute labour to take the places of those away on courses, the Ministry will arrange for trainees to be sent from Government training establishments. In appropriate cases, also, the Ministry is prepared to provide some financial assistance to employers, to meet expenses that may be incurred because of a man's absence. Employers who are in need of further skilled personnel for setting or for tool-room work and are unable to train their own men, are urged to communicate with the Ministry's Divisional Controller in their area or with the nearest Employment Exchange. A leaflet, No. P.L. 92/1941, describing the facilities available under the scheme, is being sent to employers in the engineering industry. Any interested employer who does not receive a copy should apply to the nearest local office of the Ministry. Where any of the present up-grading courses does not meet an employer's needs, the Ministry will make every effort to arrange a suitable course.

REINFORCED-CONCRETE BARGES.

It has been known for some time that the Admiralty, which now controls all ship construction in this country, has had under consideration the building of concrete barges as a possible means of economising in the use of steel, as was done to a limited extent in the last war; though some doubt has always been felt in orthodox shipbuilding circles whether the expedient was worth the considerable sums that were then expended in producing the relatively small number of such craft that were actually put into service. Presumably, the lessons then learned, and the large and varied experience since gained in reinforced-concrete construction of all kinds, are held to justify a revival of the type, as it has been announced recently that a number of these barges have been ordered, some of which are to be built of precast slabs, with connecting frames and floors cast *in situ*. The decision to re-introduce concrete barges was actually taken more than a year ago, and several different forms of construction are understood to be undergoing practical trial. The carrying capacity is 200 tons, and the design is based on that of the ordinary Thames barge, but with ship-shaped ends. The light weight of a reinforced-concrete barge is stated to be about twice that of a steel barge of equal deadweight capacity; but the weight of steel required is only about one-third. The cost of construction is said to be about the same as the cost of a steel barge; and, under favourable conditions, a barge built of pre-cast slabs can be assembled and completed in about eight weeks. So far as we are aware, it is not proposed to construct any power-propelled craft of reinforced concrete.

THE SOUTH AUSTRALIAN RAILWAYS.

The annual report of the South Australian Railways Commissioner for the year ended June 30, 1940, which has only recently come to hand, shows a net increase in earnings of 50,189*l.* over the figures for the previous year, although the working expenses per mile and the cost of working, per train-mile, were both slightly higher. The improvement in earnings is principally accounted for in the carriage of wheat, the receipts from this traffic being 25,124*l.* better than the amount, 276,894*l.*, received in 1938–9; and from passengers, mainly second class, this source contributing 29,395*l.* more, of which 1*l.* only represented the increase from first class fares—a remarkable consistency to be shown by two consecutive years, one of peace and the other, three-fourths a war year. There was increased traffic in wool and also in general merchandise, but a decrease in the earnings from mineral freights. The total train-miles run was 5,928,416, compared with 6,177,407 in 1938–9, the average mileage per ton of freight and livestock being 124·8, as against 131·0 in the previous year. Most of the livestock transported consisted of sheep, of which nearly 3½ millions were carried. Cattle, calves and horses numbered rather more than 145,000, and other livestock (mainly pigs), rather more than 90,000. The total mileage of track open for traffic was 2,557, of which 1,077 miles were of 3 ft. 6 in. gauge and 1,480 miles, 5 ft. 3 in. gauge. The rolling stock comprised 330 locomotives, 622 coaching vehicles, and 7,454 goods and livestock vehicles. The number of employees was 8,374. The number of passengers carried increased from 17,528,651 to 17,641,766, the average mileage per passenger being 76·85 on the country routes and 7·08 on the suburban services. By far the greater part of the passenger traffic was suburban, mainly in and around Adelaide, 16,278,455 out of the above total of passenger journeys coming into the suburban category. No persons, passengers or employees, were killed in train accidents during the year covered by the report, and only 9 passengers were injured—a figure which represents approximately one injury in 2,000,000 miles of travelling. Of the total operating expenditure of 2,950,081*l.* during the year, maintenance of way and works accounted for 500,617*l.* and "transportation and traffic," 689,681*l.* The latter figure does not include the expenditure directly chargeable to rolling stock, the maintenance of which absorbed 638,226*l.*, or the cost of locomotive power, which was 705,831*l.* The general superintendence of rolling stock amounted to 23,105*l.*, and the examination and lubrication of coaching and goods vehicles, 17,072*l.* In the report of the Mechanical Engineering Branch, it is noted that 5,552 gals. of car and wagon oil, 4,413 gals. of motor oil (presumably from road vehicles) and 1,780 lb. of grease were reclaimed, together with 18 tons of waste for axle-boxes. Fourteen new boilers were constructed in the railway shops in the course of the year, in addition to a certain amount of new rolling stock, mainly for the 3 ft. 6 in.-gauge lines. No new locomotives were added during the year, but 38 were in hand for heavy repairs, as against 46 in 1938-9. The Islington workshops of the Mechanical Engineering Department have been largely engaged on munitions work and have been extended for this purpose.

POST-WAR PLANS IN THE UNITED STATES.

In view of the recent debate in the House of Lords, to which we referred on page 7, *ante*, when the need was stressed for a central planning authority to deal with the many problems of reconstruction that will arise as soon as hostilities cease, it is interesting to note that in the United States the necessity for some similar provision is also clearly realised and that action is being taken already to prepare for the onset of peace. According to the *Engineering News-Record*, the Federal Works Agency has set up an organisation, known as the Public Works Reserve, which is to co-ordinate the functions of state and local agencies in formulating an immense programme of public works, for the initiation of which all possible preparations are to be made, including the detail design. At the present time, some 2½ million dollars are available for the purposes of the Public Works Reserve, but a Bill was introduced in Congress in June, by Senator Wagner, which is designed to place large additional funds at the disposal of the Federal Works Agency for the advance preparation of plans. No amount is specified in the Bill, but it is understood by our contemporary that "the administration is thinking in terms of about 50,000,000 dols." If the Bill is passed, the Public Works Reserve is expected to become the nucleus of a much larger organisation, but, meanwhile, it is pressing forward with the preliminary arrangements. It is proposed to appoint a representative, preferably an engineer, in each state, whose duty will be to approach the local administrations in their areas and to ask them to formulate plans for public works that may be needed, for submission to the Public Works Reserve. The Reserve, at present, has no funds available to finance this work in the various districts, but is prepared to lend the services of technical personnel to assist in framing the estimates which are an essential feature of the scheme. These estimates will be approximate only in the first instance, but, in districts which already have a public-works plan in hand, detailed designs of selected proposals would be proceeded with, again with the assistance of the Reserve in finding the necessary skilled staff, should this be necessary. The co-ordination of these local schemes with Federal activities is being maintained through the National Resources Planning Board and a special committee of representatives of all the Federal construction agencies. It is foreseen, however, that there may be considerable difficulty, in present circumstances, in finding a sufficient number of competent men to handle an undertaking of such wide scope, in view of the many demands now being made by the Government and private industry upon the available reserves of experienced public-works technical staff.

THE RAILWAY EXECUTIVE COMMITTEE.

Colonel J. J. Llewellin, Parliamentary Secretary to the Ministry of War Transport, announced in the House of Commons on August 7 that Sir Ralph Wedgwood, C.B., Chairman of the Railway Executive Committee since its formation at the outbreak of the war, had resigned that position. In his place, the Minister of War Transport had appointed Sir Alan Anderson, G.B.E., to be chairman and also to hold the new post of Controller of Railways in the Ministry. On taking up the appointment, Sir Alan Anderson had relinquished his seat on the board of directors of the London Midland and Scottish Railway. Sir James Milne, general manager of the Great Western Railway, who also had been a member of the Railway Executive Committee since its inception, had been appointed deputy chairman. Colonel Llewellin added, in response to a question, that Sir Alan had declined the salary that had previously attached to the chairmanship of the Committee. As originally constituted, the Railway Executive Committee comprised Sir Ralph Wedgwood, Sir James Milne, Sir William Wood (vice-president, L.M.S. Railway), Mr. G. S. Szlumper (general manager, Southern Railway), Mr. C. H. Newton (chief general manager, London and North Eastern Railway) and Mr. Frank Pick (London Passenger Transport Board). Soon afterwards, however, Mr. Szlumper was appointed Director-General of Transportation and Movements, at the War Office, but relinquished this position a year later to become Railway Control Officer at the Ministry of War Transport. His place on the Committee was taken by Mr. E. J. Missenden, who had also succeeded him as general manager of the Southern Railway. Mr. Frank Pick left the Committee in May, 1940, to become Director-General of the Ministry of Information, and was succeeded by Lord Ashfield, chairman of the London Passenger Transport Board.

LETTERS TO THE EDITOR.

A THEORY OF THE KADENACY SYSTEM.

To the Editor of Engineering.

Sir,—In his letter of July 25, published in your issue of August 1, on page 94, Dr. Geyer correctly interprets my criticism of his article on the Theory of the Kadenacy System. I could not and, in spite of the figures he gives, still cannot agree that the escaped gases are moving with constant velocity. I do agree with him that, in the first part of the discharge, the velocity in the port is equal to the acoustic velocity under the pressure and temperature conditions prevailing there and accept his figure of 1,025 ft. per second for the initial port velocity. It would appear, however, that this equality between velocity of discharge and acoustic velocity should hold until the cylinder pressure is equal to atmospheric pressure $\div 0{\cdot}528$, *i.e.*, until the port pressure has fallen to atmospheric. I submit a calculation of the acoustic velocity in the port for this instant:

$$\text{Port temperature} = 525 \times \left(\frac{14{\cdot}7}{74{\cdot}7}\right)^{\frac{2}{7}} = 330 \text{ deg. F. abs.},$$

$$\text{density in port} = \frac{144 \times 14{\cdot}7}{53{\cdot}3 \times 330}$$

Substituting these in the well known formula for acoustic velocity,

$$V = \sqrt{\left(\frac{P g \gamma}{\rho}\right)}$$

gives

$$\sqrt{\left(\frac{14{\cdot}7 \times 144 \times 32{\cdot}2 \times 1{\cdot}4 \times 53{\cdot}3 \times 330}{144 \times 14{\cdot}7}\right)} = 892 \text{ feet per second}$$

as the acoustic velocity, and also as the velocity of discharge in the port at this instant.

I feel that over this part of the discharge alone there is a sufficient variation to render invalid any assumption of uniform velocity, particularly as the square of the velocity appears in the energy equation. It must also be borne in mind that, during the period considered above, the gas is emerging at a pressure higher than that of the atmosphere and will, after leaving the vessel, expand further, acquiring additional velocity in the process to a degree depending on its pressure of emergence. For the portion of the gas referred to above, I would suggest that the highest velocity present when atmospheric pressure is reached—the condition to which the energy equation refers—is of the order of 1,530 ft. per second, the first figure quoted by Dr. Geyer in his letter. During the subsequent part of the discharge the emergent velocity cannot exceed the now constant acoustic velocity of 892 ft. per second and will, in all probability, fall progressively below this figure as the discharge continues, thus giving an extremely wide range of velocities to be dealt with. May I suggest that the value of 1,060 ft. per second obtained by Dr. Geyer is something in the nature of a mean, or rather a root mean square, value for the whole of the escaped gases and that he is crediting the gas leaving the port at the instant of pressure equalisation with this velocity whereas it will really be moving very much more slowly?

Yours faithfully,
F. K. Bannister.

The University, Birmingham.
August 11, 1941.

THE PURIFICATION OF SALT WATER.

To the Editor of Engineering

Sir,—In view of the correspondence that has appeared in the columns of *The Times*, followed by your leading article under the above heading and, to use your own words the "challenge to every engineer and physicist," we would inform you that the process mentioned has been in commercial operation in this country for the past four years. The process is known as "The Demineralisation of Water" and is carried out under patents and licences owned by this Company. We enclose a copy of our publication entitled "Distilled Water without Distillation," and on page 4 of this you will see that it is stated that as "an extreme case, it is even possible to convert sea water into a drinking water supply."

Yours faithfully,
The Permutit Company, Limited,
R. T. Pemberton.

Gunnersbury Avenue, London, W.4.
August 11, 1941.

OBITUARY.

PROFESSOR J. C. PHILIP, O.B.E., F.R.S.

We note with regret the death of Professor James Charles Philip, which occurred suddenly in a nursing home on August 6. Professor Philip was Professor Emeritus of Physical Chemistry, Imperial College of Science and Technology, South Kensington. He was the youngest son of the late Rev. John Philip, D.D., and was born at Fordoun, Kincardineshire, on February 12, 1873. He received his general education at Fordoun Public School and at Aberdeen Grammar School and afterwards entered Aberdeen University, where, in 1893, he was awarded the Aberdeen Town Council Gold Medal and received the M.A. Degree. Two years later he was made a Murray Scholar and proceeded to Göttingen University, where he obtained a Ph.D. Degree in 1897, and on his return to this country he became assistant to the two famous research workers, C. T. Heycock and F. H. Neville, at Cambridge University. Professor Philip's long association with the Colleges at South Kensington began in 1900 when he was appointed demonstrator and lecturer at the Royal College of Science. In 1909 he was made assistant professor of chemistry in the Imperial College of Science and Technology and continued in this capacity until 1913 when he was appointed Professor of Physical Chemistry. He occupied this position until his retirement in 1938. He was made director of the inorganic and physical laboratories at Imperial College in 1932.

Professor Philip was the author of several books, including *Romance of Modern Chemistry*, published in 1909, and *Achievements of Chemical Science*, published in 1913. He received the Degree of D.Sc. of Aberdeen University in 1906, was made an O.B.E. in 1918, and elected an F.R.S. in 1921. He was for many years a Fellow and member of the Council of the Chemical Society, and served as Secretary from 1913 until 1924. He became a Fellow of the Institute of Chemistry in 1919, serving on the Council from 1922 until 1925, and was President of the Society of Chemical Industry from 1939 until the present year.

SIR JOHN PRIESTMAN, BART.

The death of Sir John Priestman, Bart., which occurred on August 5, at his Harrogate residence, removes a well-known figure from shipbuilding and industrial circles on the North-East Coast. Sir John, who was 85 years of age, was sole proprietor of the firm of Messrs. John Priestman and Company, shipbuilders, Southwick, Sunderland. He was born at Bishop Auckland, County Durham, and after attending school in his native town, served an apprenticeship to shipbuilding with Messrs. John Blumer and Sons. He subsequently became a draughtsman and was in charge of the drawing office of two Wearside shipbuilding concerns. In 1882, he founded the shipbuilding firm which bears his name. Sir John was chairman of the Enfield Steamship Company and the Brinkburn Steamship Company, Limited, Sunderland, and of the Cliffside Steamship Company, Limited, Newcastle-upon-Tyne. In addition, he was largely interested in a number of coal, iron and steel, and other commercial and industrial undertakings. Sir John received a knighthood in 1923 and was created a baronet in 1934. In recognition of his many philanthropic gifts to the town of Sunderland, which included a donation of 20,000*l.* for the erection of a library at the Technical College, he received the Freedom of the Town in 1933. Sir John was County Magistrate for Durham and chairman of the Urban District Council of Southwick-on-Wear.

SPRINGS FOR MAXIMUM RESILIENCE.

By J. Jennings, B.Sc., A.M.I.Mech.E.

The torsional strain energy of a round elastic shaft, subjected to a maximum shear stress q, is given by

$$e = \frac{q^2}{4\,G} v \quad . \quad . \quad . \quad (1)$$

where v is the volume of the material and G is the modulus of rigidity. The simple theory of the close-coiled helical spring assumes that the action on the wire is exactly similar to that on a straight twisted shaft, and accordingly the energy stored will be as given by the above formula. It would appear, therefore, that if a spring is to be used to store a given amount of energy, it is only necessary to provide the requisite volume of wire to limit the shear stress to a safe value; and, subject to this, it is immaterial how the wire diameter, coil diameter, and number of coils are varied. It is known, however, that the stress distribution in a close-coiled spring is different from that in a straight shaft, on account of the curvature of the wire and because of the direct shear action produced by the load. Both of these effects are functions of the coil-wire diameter ratio $\frac{D}{d}$, the discrepancy between the actual maximum and that derived from the simple formula increasing as $\frac{D}{d}$ becomes smaller. The volume of wire to be used to limit the stress to a given value will be smaller, therefore, for higher $\frac{D}{d}$ ratios.

A number of empirical formulæ have been proposed by various authorities for the maximum shear stress induced in a spring, and these have been compared in a recent paper before the Institution of Mechanical Engineers.* In this it was shown there that these formulæ give results which agree very closely over a wide range of the ratio $\frac{D}{d}$. The corrected formula for the maximum shear stress induced is

$$q = \frac{8\,W\,D\,k_1}{\pi\,d^3} \quad . \quad . \quad . \quad . \quad (2)$$

where k_1 is the stress correction factor, and W is the maximum load applied to the spring.

Wahl's factor is

$$k_1 = \frac{4c-1}{4c-4} + \frac{0{\cdot}615}{c},$$

where

$$c = \frac{D}{d} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The deflection due to a given load is greater than that calculated by the simple formula, and a correction proposed by Wood, in the discussion on Wahl's paper,† is

$$Y = \frac{8\,W\,D^3\,n\,k_2}{G\,d^4} \quad . \quad . \quad . \quad (4)$$

where

$$k_2 = \frac{2c^2 + c - 1}{2\,c^2} \quad . \quad . \quad . \quad (5)$$

and n is the number of coils.

The introduction of the corrections into the energy formula (1) gives

$$e = \frac{k_2}{k_1^2} \frac{q^2}{4\,G} v. \quad . \quad . \quad . \quad (6)$$

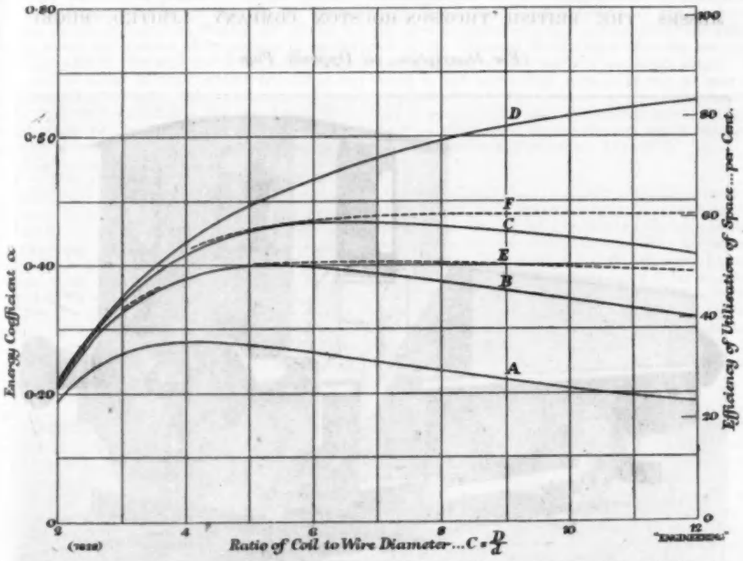
Some calculated values of these correction factors are given in Table I, on the opposite page.

The energy correction factor $\frac{k_2}{k_1^2}$ will be seen from the Table to be very important. Even at $\frac{D}{d} = 8$, the energy stored for a given maximum stress is only 75 per cent. of that of a straight twisted shaft. Square wire, on account of less economical use of material, can only store 61 per cent. of the energy for a given stress stored by a round wire of similar size. Phosphor-bronze wire, which has a modulus

* "Practical Problems in Spring Design," by W. R. Berry. *Proc. I. Mech. E.*, vol. 139, pages 502-6 (1938.) Discussion by J. R. Finniecome.

† *Trans. A.S.M.E.*, vol. 51, part 1 (1929).

SPRINGS FOR MAXIMUM RESILIENCE.



of 6,000,000 lb. per square inch and a safe stress of about 0·45 of that of carbon-steel wire, can store approximately 40 per cent. of the energy possible with round wire of that material.

The volume of wire used in a spring, however, is usually unimportant compared with the space which the spring occupies. This space often affects the size of castings, or other parts much more expensive than the spring itself. A more important criterion to consider than the energy per unit volume of wire will be energy per unit volume of space occupied. The most suitable and convenient volume to use in this connection appears to be that which encloses the effective part of the spring when the coils touch. This is

$$V = \frac{\pi}{4}(D + d)^2 n d \quad . \quad . \quad . \quad (7)$$

The energy formula now becomes

$$e = \frac{\pi c}{(c+1)^3} \frac{k_2}{k_1^2} \frac{q^2}{4G} V \quad . \quad . \quad (8)$$

where $c = \frac{D}{d}$ as before.

For the maximum resilience of a nest of such springs, it is essential that the solid length shall be the same for each. If it be assumed as two further conditions that the total deflections are the same, and that the internal surface of an outer spring just touches the external surface of an inner spring, equation (10) may be simplified. The total proportional deflection of a spring is given by eliminating W from equations (2) and (4), and is

$$\frac{Y}{n d} = \frac{\pi q}{G} c^3 \frac{k_2}{k_1} \quad . \quad . \quad . \quad (11)$$

Thus, if Y and $n d$ are fixed, it is necessary that c shall also be the same for each spring. Since α is a function of c only, equation (10) may be written

$$e = \left(1 + \frac{V_2}{V_1} + \frac{V_3}{V_1} + \ldots\right) \alpha \frac{q^2}{4G} V_1.$$

Because $n d$ is the same for each,

$$\frac{V_2}{V_1} = \left(\frac{D_2 + d_2}{D_1 + d_1}\right)^3;$$

TABLE I.—CALCULATED CORRECTION FACTORS.

$\frac{D}{d}$	3.	4.	5.	6.	8.	10.	20.
Stress correction factor	1·580	1·403	1·310	1·252	1·184	1·144	1·069
Deflection correction factor	1·111	1·064	1·080	1·070	1·055	1·045	1·024
Energy correction factor	0·446	0·555	0·630	0·681	0·752	0·797	0·898

This formula may be written

$$e = \alpha \frac{q^2}{4G} V, \quad . \quad . \quad . \quad . \quad (9)$$

where α is a function of c. Values of α have been plotted (Curve A) in the accompanying graph, and α has a maximum value of 0·279 at $\frac{D}{d} = 4{\cdot}2$. Safe working stresses for plain carbon spring steel wire vary from 50,000 lb. to 80,000 lb. per square inch. Putting G at an average value of 11,600,000 lb. per square inch, this gives a maximum resilience ranging from 15 in.-lb. to 39 in.-lb. per cubic inch of space. Chrome-vanadium spring steel has a safe working stress about 1·4 times that of the normal steel, and, therefore, the resilience possible with it will be twice the above values.

To increase the concentration of energy in a given space, two or more springs, one within the other, may be used. Referring to equation (9), it will be seen that the energy stored by a number of springs for a given maximum stress is given by

$$e = (\alpha_1 V_1 + \alpha_2 V_2 + \alpha_3 V_3 + \ldots) \frac{q^2}{4G} \quad (10)$$

and, since the springs touch, $D_2 + d_2 = D_1 - d_1$, therefore,

$$\frac{V_2}{V_1} = \left(\frac{D_1 - d_1}{D_1 + d_1}\right)^3 = \left(\frac{c-1}{c+1}\right)^3.$$

Similarly,

$$\frac{V_3}{V_2} = \left(\frac{c-1}{c+1}\right)^2;$$

therefore

$$\frac{V_3}{V_1} = \left(\frac{c-1}{c+1}\right)^5,$$

and

$$e = \left\{1 + \left(\frac{c-1}{c+1}\right)^3 + \left(\frac{c-1}{c+1}\right)^5 + \ldots\right\} \frac{\alpha q^2}{4c} V_1. \quad . \quad . \quad (12)$$

The value of e from this equation, for one, two, three, and an infinite number of springs, has been plotted in the accompanying diagram as curves A, B, C, and D, respectively. It will be seen that the maximum resilience with two similar springs occurs at $c = 5{\cdot}5$, and with three similar springs at $c = 6{\cdot}5$. An absolute maximum would occur for an infinite number of springs of infinitesimally thin wire. In this case, the volume of wire would be $\frac{\pi}{4}$ times the volume of the space, and, therefore,

$$e_{max} = \frac{\pi}{4} \frac{q^2}{4G} V_1. \quad . \quad . \quad . \quad (13)$$

This may be regarded as an ideal figure and the resilience of other springs or groups may be given as a fraction of it. This fraction would represent the efficiency of utilisation of the space for the storing of energy. Thus, for a single spring, the greatest possible efficiency is 35·6 per cent.; with two springs, having equal values of c, it is 50·6 per cent.; and, with three such springs, it is 59·5 per cent.

It would appear possible to increase the efficiency of a given space by varying the value of c among the springs. The inner spring could then have the best value for a single spring, that is, 4·2. The best outer spring to go with this particular inner spring is one having a value of c between 6 and 7. This is the best possible combination of two springs, and the energy coefficient is 0·404, or the efficiency 51·5 per cent. (Curve E). The best combination of the three springs would be the two, given above, combined with an outer spring having c between 8 and 10, the energy coefficient being 0·477, and the efficiency 60·7 per cent. (Curve F).

In this system the maximum resilience is approximately 2 per cent. greater than in the constant $\frac{D}{d}$ system. Because of the varying values of $\frac{D}{d}$, the deflections of the springs will vary, the outer spring taking the load first. In the constant $\frac{D}{d}$ system, all the springs of a nest have the same period of vibration, whereas the period varies with the latter system. This may be an advantage where vibration troubles are likely to occur, since the building up of a vibration will become impossible. If the springs of a nest are to have constant wire diameter, it will be seen that the $\frac{D}{d}$ ratios should increase outwards by 2 at a time if the coils touch, or slightly more, allowing for clearance. The latter system has ratios of c or $\frac{D}{d}$ about 4·2, 6·5, and 9·0, which falls in with this condition approximately. Thus a very convenient rule emerges—that the wire diameter should be the same for each spring, subject to a coil-wire diameter ratio of about 4·2 for the inner spring.

RESTRICTION OF MOTOR-VEHICLE IMPORTS INTO SIERRA LEONE.—The importation into Sierra Leone of all motor vehicles and spare parts from the United Kingdom is prohibited, except under licence.

CONTROL OF FACTORY AND STORAGE PREMISES.—On page 93, *ante*, we referred editorially to the Location of Industry (Restriction) Order, 1941, which prohibits, except under licence, the use of factory and storage premises for trades or businesses not previously carried on there. We have now received from the Board of Trade a list of the Regional Offices to which applications may be made for licences. They are as follow: *Northern Region* (Northumberland, Durham and North Riding of Yorkshire), 34, Grainger-street, Newcastle-on-Tyne (Tel., Newcastle 28831); *North Eastern Region* (East and West Ridings of Yorkshire), Woodville House, 29, Vesper-road, Kirkstall, Leeds, 5 (Tel., Headingley 54107); *North Midland Region* (Derbyshire, Nottinghamshire, Lincolnshire, Leicestershire, Northamptonshire and Rutland), Dudley Lodge, Peveril-drive, Nottingham (Tel., Nottingham 41025); *Eastern Region* (Cambridgeshire, Bedfordshire, Huntingdonshire, Norfolk, Suffolk, and Hertfordshire and Essex outside of the Metropolitan Police Area), G. F. S. House, Park-terrace, Cambridge (Tel., Cambridge 56206); *London and South Eastern Region* (Metropolitan Police Area, Surrey, Kent and Sussex), 25, Victoria-street, London, S.W.1. (Tel., Abbey 3206; *Southern Region* (Oxfordshire, Buckinghamshire, Berkshire, Hampshire and Dorsetshire), Burberry-buildings, Mill-lane, Reading (Tel., Reading 4851); *South Western Region* (Gloucestershire, Wiltshire, Somersetshire, Devonshire and Cornwall), 11, Chantry-road, Bristol, 8 (Tel., Bristol 37604); *Wales*, 10, Cathedral-road, Cardiff (Tel., Cardiff 5803); *Midland Region* (Staffordshire, Warwickshire, Worcestershire, Herefordshire and Shropshire), Somerset House, 37, Temple-street, Birmingham, 2 (Tel., Midland 3076); *North Western Region* (Cheshire, Lancashire, Westmorland and Cumberland), Lombard-chambers, 46, Brown-street, Manchester (Tel., Deansgate 2578); and *Scotland*, 95, Bothwell-street, Glasgow, C.2 (Tel., City 6511).

POST-WAR DEVELOPMENT OF INDUSTRIAL GAS.*

By H. R. Hems, Assoc.M.Inst.Gas E.

The effect of the present conflict upon the gas industry has been to place the demand for gas for industrial purposes on a level which might have taken years of patient work to achieve. History has again repeated itself. At the commencement of the last war, industrial gas development, only in its infancy, was given an impetus enabling it to achieve in four years a place in fuel utilisation which might never have been obtained under ordinary commercial conditions.

A feature of the present state of supply of gas to industry is the possibility in any area of temporary cessation of supply or detrimental interference with pressure conditions within a factory, which has made many executives realise more than ever before the value of the town gas supply. Reports of large increases in the demand for industrial gas come from all gas undertakings in a position to supply. The large undertakings are probably not finding difficulty in supplying, owing to reduction in demand due to black-out, evacuation, and other causes; some have even found total outputs on the increase. Smaller undertakings, especially those in the manufacturing areas, have found, owing to increased consumptions of existing factories and to the dispersal of factories into their areas, relatively enormous demands being made on their capacity.

Here are circumstances which set a post-war problem affecting industrial gas supply. Will the concentration of factories continue in confined areas with surrounding residential areas, or will the future bring a return of population to the cities and place the factories in areas surrounding such cities? The trend will be decided by social policy after hostilities cease, but it is suggested that the smaller undertakings will be far more interested in the industrial load than in the past. Prior to hostilities, many returns revealed a rising percentage of gas sold for industrial purposes. These percentages have, no doubt, risen sharply in recent months. As the value of town gas for industrial work has now been so widely recognised by manufacturers, it seems logical that (i) undertakings should set their policies to maintain and still further extend its use, and (ii) that a national fuel policy should be instituted which takes full cognisance of the remarkable development of the use of gas in industry.

After the war there will be a greater need than ever for fuel utilisation—particularly in industry—to be placed in its proper perspective. The first consideration should, of course, be to use the national resources to the fullest extent. A reversion to the use of raw coal is unlikely in many industries, particularly as, in modern production methods, heat-treatment applications are placed as close as possible to the general line of production. The manufacturer will use the most convenient form of fuel to meet the situation, sometimes without reference to the economics of competing fuels.

It has always appeared unsatisfactory that a nation which has natural fuel available should be purchasing from overseas before making the fullest use of its own resources, and at the same time having to pay for the enforced idleness of many engaged in its own fuel industry. This is not to be taken as a biased view of a competitor; imported fuels have a most valuable place in industry. But all fuels, whether home-produced or imported, should be applied in the most scientific, practical, and economic way to the various demands of the industries of the country. This would necessitate a survey of the whole field of industrial fuel application, but the value of a balanced allocation of fuels would assist the nation's economic programme in peace time.

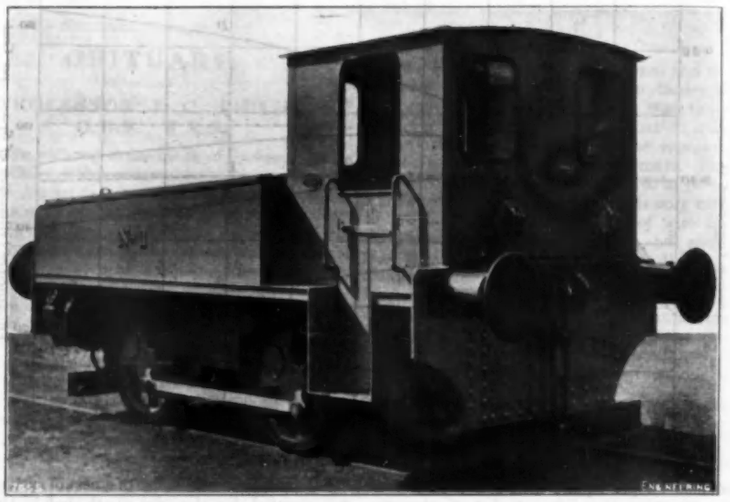
Town gas as an industrial fuel will have to be ready to take its place among competitors which have increased their prestige and value on both technical and economic grounds. It will be more than ever necessary, if we desire to increase the use of town gas in industry, in the first place, to assist in every way the development, research and improvement in design of furnaces and apparatus for its utilisation, and secondly, to endeavour to set a price policy. One of the great disadvantages of general development of the use of industrial gas has been the varying charges in different parts of the country. Is it too much to hope that a more uniform price policy might be adopted, particularly for certain processes which are common to the whole country? It would be greatly appreciated by executives who value the industrial load, offering possibilities of improving load factor in relation to works gas-making capacity and distribution, which would result in a reduction of overhead charges; this, generally, with a low cost of servicing and many other factors, should lead to the tariffs for industrial gas being brought to a level at which it would be in a better position to compete with other fuels.

* Paper presented at the 78th Annual Meeting of the Institution of Gas Engineers, held in London on June 11, 1941. Abridged.

BATTERY LOCOMOTIVE FOR INDUSTRIAL HAULAGE.

MESSRS. THE BRITISH THOMSON-HOUSTON COMPANY, LIMITED, RUGBY.

(For Description, see Opposite Page.)



Industries have always put forward the basis for the development of furnace practice by communicating their needs to furnace makers, or more recently, to suppliers of fuel or energy. Means of contact with manufacturers must therefore be maintained by personnel with the necessary training in industrial processes, in order to obtain first-hand information on changes of process which may affect existing gas-furnace practice, necessitating new technique in furnace development. Research into the application of gas to the new process may then have to be made by the gas industry, with the collaboration of the furnace maker.

Interchange of ideas and experience in gas furnaces and application practice, which has taken place in the past through the Industrial Gas Centres, will have to continue, and the work of their co-ordinating committee must be widened considerably. Industrial-gas engineers have, with certain exceptions, sprung from within the gas industry. If the development of the industrial gas load is to progress, they should become more in the nature of specialists in individual trades and processes, and, with the exception of the large undertakings, their training and experience should be at the disposal of more than one gas undertaking. This may mean setting up a laboratory for research and testing of furnaces and industrial appliances, suggestions regarding which have already been put forward. The use of such a laboratory and the results of its work should be available to the gas industry as a whole, including furnace and apparatus makers. Excellent new ideas and designs are often condemned by a user because they have been "tried out" on him, and a laboratory incorporating the work of designer, maker, fuel supplier and user would prove of the greatest value and tend to reduce the possibility of trial runs being failures.

Increased speed of production and cleanliness of the product during any heat-treatment process seem to be predominant features of changes in heat treatment, and are likely to remain so. The furnace of the future must embody characteristics meeting these demands; in other words, to fulfil the first condition, as heat-treatment operations have usually very definite time factors, it must become a machine as well as a furnace, to reduce handling time. Makers are already producing furnaces to meet the demand for continuous production. The fact that, in the design of many competitive fuel furnaces, town gas is imperative in order to provide the atmosphere necessary to give cleanliness of production, whether in its ordinary state or refined, indicates that the gas industry has a primary product suitable for meeting the second demand—that of cleanliness. Tubular heating and the development of gas "atmosphere" plants were brought to a practical state just prior to the war, and have proved their value in war production, which, of necessity, takes advantage of all previous experience and applies a rigid test.

As one instance of a special process, one may take the increased use of light alloys, particularly in aircraft production, which offers a fine field for research and improvement in gas-furnace design and practice after the war. In furnaces for the forging and heat treatment of these alloys, the use of some "medium" in the form of liquid salts or moving heated air is now accepted practice, and sets a line of development for the future which is full of possibilities. Already it can be seen that the liquid medium is likely to be displaced in many operations by air as the heat-transferring medium; not as yet, of course, where liquid salts are used as the high-temperature media in the case of high-speed steel tools, or where some definite transfer of a chemical nature takes place, as, for example, in the use of cyanide and other salts as carburising agents.

Temperatures in which moving air is used as a medium of heat transfer are at present of a comparatively low range; in the light-alloy industry, usually of the order of 535 deg. C. There seems little reason to doubt that the temperature range can be raised considerably, bringing in extra fields of industrial gas application. With suitable instruments, town gas can provide all the control of temperature vital to the use of air as a heating medium, and with correct application there is no reason why it should not meet new and higher temperature developments; in fact, having overcome difficulties with regard to the lower range in which any incandescent mass is difficult to utilise, it should be readily adaptable to the higher temperature ranges where refractory materials would have to be employed in the combustion chambers. The recent work of the British Standards Institution on Standard Specifications for Furnaces will have to be applied in the future. The possibilities of improvement in efficiencies of the more ordinary types of furnaces, for which there will always be a demand, are by no means exhausted. Work on outside finish is very necessary; the presentation of final furnace design in suitable external casings has been the subject of much discussion by the Industrial Gas Centres Committee, and recently considerable improvement has taken place.

Much work still remains to be done on the smaller types of burners and appliances, the consumptions of which mount to large figures when taken in the aggregate, and probably constitute a main source of application for industrial loads in many districts. These appliances are often overlooked when work on the larger types of furnaces is discussed, but they are of considerable importance.

The Chester Ring Road.—An Order, entitled the Swansea-Manchester and Chester-Bangor Trunk Roads (Chester Ring Road-Southern Section) Order, 1941, has been issued by the Minister of War Transport. This lays down that, as from July 8, the Southern Section of the Chester Ring Road from a point on Road A.51, roughly 950 yards east of the boundary of the County Borough of Chester to the junction of Sandy Lane with the Chester-Bangor trunk road, becomes a trunk road, superseding certain parts of the existing trunk roads. The portion of the route lying within the Borough of Chester, however, is excluded from the Order.

BATTERY LOCOMOTIVE FOR INDUSTRIAL HAULAGE.

THE battery locomotive, illustrated on the opposite page, has been designed by Messrs. The British Thomson-Houston Company, Limited, Rugby, for service in an industry where the absence of fumes, grit or sparks in the haulage unit is very desirable. It is capable of hauling a load of about 75 tons on the level and is replacing a Diesel locomotive which had been used as a temporary expedient for similar duties. Apart from the characteristic of clean working just referred to, the battery locomotive is silent in operation, is immediately available, and there are, of course, no stand-by losses. It will be clear from the figure that there are four coupled wheels only. The wheel base is 5 ft. 3 in., and the gauge is the standard British railway gauge, so that sharp curves are readily negotiated. The wheels are balanced with weights opposite the coupling-rod pins. The locomotive weighs 10½ tons.

Only one of the axles is driven, a single traction motor rated at 20 h.p. being geared to it. The motor armature runs in roller bearings, and both suspension bearings are fed from a common oil well. The axle-box oil wells and side-rod bushes are accessible from outside the locomotive. The current supply, of 150 volts to 200 volts, is derived from a 380 ampere-hour N.I.F.E. battery of 124 cells. Control is by means of a drum-controller of standard tramway design modified for single motor operation. The spare contacts on the reversing cylinder of the controller are utilised to effect the change-over in the head and tail lighting, according to the direction of travel of the locomotive. Other electrical equipment is on normal lines and includes two circuit-breakers, a meter of the Sangamo type, a charge and discharge ammeter, a voltmeter, and appropriate lighting switches. The accelerating and braking resistances are of edge-wound strip construction. Rheostatic braking and hand braking are provided on all four wheels.

The battery is charged from a rectifier sub-station adjacent to the running shed, but it is also boosted up during the mid-day dinner interval of the factory. The buffers and couplings suit ordinary stock, but the buffer plate is prolonged to the bottom of the side frames and carries a line-clearing bar just above the rails. The cab is roomy and is provided with large windows for both directions of travel, while hinged half-doors give additional look-out facilities with adequate protection to the driver.

SWEDISH INDUSTRIES FAIR.—War emergency substitutes were included in the exhibits at the Swedish Fair recently held at Gothenburg. Among the apparatus shown were various types of wood or charcoal consuming gas producers for motor cars, tractors, motor boats and stationary engines; boilers and furnaces specially developed to burn wood or peat; and insulating materials made of paper and boards.

THE MEXICAN OIL INDUSTRY.—During the first quarter of the present year the output of petroleum in Mexico totalled 9,394,080 barrels, compared with 10,064,107 barrels in the first three months of 1940. Exports declined similarly, from 4,693,632 barrels, in the first quarter of last year, to 3,567,808 barrels in the January-March period of 1941. Practically the whole of the last-named quantity was consigned to ports in the United States.

PHOTOGRAPHY APPLIED TO PLAN COPYING.—A booklet has been issued recently by Messrs. Ilford, Limited, of Ilford, London, in order to give a brief explanation of the various photographic processes available for the reproduction of drawings, documents, etc., so that prospective users may select the process most suitable for their own requirements. Same-size reproduction by contact and reflex copying is first referred to, and it is explained that in the latter process the Reflex paper is placed in contact with the original and exposed through the back of the sensitive paper. The method can be employed if there should be writing on the back of the drawing so that it would be impossible to print through the latter, but as the negative is reversed from left to right it is necessary to print a positive from it. Methods of making reduced reproductions and reduced negatives for subsequent enlargement, which necessarily involve the use of some form of camera, are also dealt with and there is a brief reference to micro-copying methods in which drawings, etc., are photographed on to 35-mm. film for storage in a very small space as an insurance against loss by fire or other damage. The latter method, although ideal for reproducing written or printed records, is not specifically recommended for plan copying, but it may be usefully employed under certain conditions. The booklet gives particulars of the various sensitive papers made by the firm and the information it contains will be interesting and useful to engineering and industrial concerns contemplating the installation of a photographic department for work of the class referred to.

LABOUR NOTES.

AT a conference in London on Thursday last week representatives of the Mineworkers' Federation of Great Britain and representatives of the coalowners discussed a number of points arising out of the application of the Essential Work Order including the conditions attached to the recently conceded bonus. The bonus, it will be recalled, is payable only to men who work full weeks. The coalowners, it was stated, undertook to consult their district associations on the points raised by the miners' representatives and it was agreed to hold a further conference on August 22.

On the following day, a report of the conference was submitted to, and discussed by, the executive committee of the Mineworkers' Federation which eventually decided to reject the conditions governing the payment of the bonus. The men, it was stated, were, however, prepared to agree to the setting up of local machinery to deal with persons who impeded production by their conduct. Mr. Lawther, the president of the Federation, explained that the executive believed that that would prove a more effective arrangement, and added, that in some areas in which it had been adopted, it had given satisfaction.

A good deal of publicity has recently been given by some newspapers to two cases in which firms declined to have anything to do with the trade unions of which a considerable number of their employees are members. In normal times employers in many industries are free to link up, or to refrain from linking up, with other firms in the same trades mainly for the purpose of negotiating with the trade unions. If they link up, their association or federation negotiates with the trade unions. On the other hand, although they may not link up, they are not left quite free of the obligation to treat with the representatives of their employees, for when, under a federation or association agreement, an Industrial Court award or a National Arbitration Tribunal finding, wage rates are increased or working conditions improved, trade union organisers take the earliest possible opportunities to bring non-federated and non-associated concerns into line. These are not, however, normal times and, considering their difficulties, there is something to be said for the wisdom of the conclusion reached by the Court of Inquiry into one of the cases alluded to. "In wartime," the Court said, "we think that however strongly individuals may desire to run their works in their own way, it is their duty to their country to fall into line with the vast majority of other good employers and assist the Government in the accepted methods of conciliation."

In their report to the Minister of Labour and National Service on the dispute mentioned in the preceding note, the Court said that the union had "acquired a membership of the overwhelming majority of the workers." The strike of shipyard workers in the New York area seems to have been due to a difference of opinion between the American Federation of Labour unions and the Congress of Industrial Organisations' unions as to which had the right to represent the workers in the plants affected. In the United States, the body entitled to negotiate with the employers is composed of the majority of the total number of workers employed. That means that in elections the semi-skilled and unskilled workers belonging to C.I.O. unions outnumber the craft operatives belonging to A.F.L. unions and, therefore, claim to be the competent negotiating body. In the case mentioned in the preceding paragraph, the union claimed only to have "an overwhelming majority" of its own members.

Under the provisions of the Essential Work Order which has been applied to the iron and steel industry, a special labour supply organisation is to be set up to secure the most economical use of man power and plant. It will be based on the normal machinery of the Ministry of Labour and National Service supplemented by local executive committees with a central co-ordinating committee. Workpeople who are temporarily surplus to the requirements of the industry will be placed on other work of national importance with the understanding that it may be necessary to withdraw them if employment in the iron and steel industry becomes available. The areas to be covered by the local committees will coincide with the civil regions.

The changes in rates of wages reported to have come into operation in Great Britain and Northern Ireland during June resulted in an aggregate increase estimated at about 300,000*l.* in the weekly full-time wages of about 1,925,000 workpeople. Of the total about 800*l.* was due to the operation of sliding scales based on fluctuations in the proceeds of the coal-mining industry, 81,800*l.* to arrangements made by joint standing bodies including 73,700*l.* under cost-of-living sliding scales arranged by such bodies, and 15,000*l.* to the operation of other sliding scales based on the cost of living. The remaining 202,400*l.* was the result of direct negotiations between employers and workpeople or their representatives.

Replying to a question in the House of Commons last week, the Minister of Labour and National Service said that under his orders, legal directions had been given for canteens at about 150 factories, including shipyards, and 25 building sites. Notices had been served on 10 dock authorities to secure improved facilities. Most canteens at such places had been, or were being, established voluntarily, and the foregoing figures were no index to the numbers of canteens in existence. New canteens had lately been completed, and opened at an estimated rate of about 100 a month. So far as he knew they were all supplied with rationed food.

Writing in the journal of the Railway Clerks' Association, Mr. Gallie, the general secretary of the organisation, expresses the opinion that there are more wages in circulation than there are goods to buy. That he regards as inevitable when a large part of production is intended to meet the Government's war requirements. The gap, he thinks, between the commodity pool and the wages pool might be explained up to a point by increased wages to individuals. But, to a much greater extent, he argues, it is due to the increased number of people who are earning money, and as the war proceeds, and more people earn money, it will become still bigger. Mr. Gallie's conclusion is that it is impossible to bridge the gap under our present economic system, although it might be substantially reduced by a more rigid price control and subsidies.

A contribution to the August issue of the Transport and General Workers Union's *Record* believes that "by a proper system of price control, rationing and currency management" inflation can be avoided. He suggests that there is some reason to believe that if the unions do not allow themselves to be put off their legitimate demands by the cry of inflation, measures of this kind will be taken.

The Governing Body of the International Labour Organisation—which is now operating from Montreal—is to hold a conference in New York on October 27. The agenda will be the acting director's report and discussion of a report on collaboration between public authorities and employers' and workers' organisations. The conference will not have the normal constitutional powers of the annual conference, and the adoption of international labour conventions is not contemplated; but the meeting will afford an opportunity for a survey of social developments throughout the world at this critical time as well as of the present and future responsibilities of the Organisation. The member States will be entitled to send delegations representing Governments, employers and workers.

According to the latest issue of *The Ministry of Labour Gazette*, the number of trade disputes involving stoppages of work, reported to the Department as beginning in June, was 82. In addition, twelve disputes which began before June were still in progress at the beginning of that month. The approximate number of workpeople involved in these 94 disputes (including workpeople thrown out of work at the establishments where the disputes occurred) was 28,000 and the aggregate duration of the disputes in June was about 89,000 working days.

Final figures compiled by the United States Bureau of Labour Statistics show that 2,508 strikes began in America in 1940 in which 576,988 workers were involved. The number of man-days of idleness caused by the strikes was 6,700,872. Half of the stoppages ending in 1940, including a third of the total workers involved and accounting for 41 per cent. of the total man-days of idleness, were primarily over the issues of union recognition, closed or union shop, discrimination, or other union organisation matters. In two-fifths of these strikes (one-fifth of the total number) demands for increased wages or decreased hours or protests against wage decreases were also in dispute, but these matters were secondary to that of union recognition.

Wage or hour issues were the primary cause of about 30 per cent. of the strikes which included 41 per cent. of the total workers involved and accounted for 46 per cent. of the total idleness. The remaining strikes (20 per cent.) which included 26 per cent. of the total workers and accounted for 13 per cent. of the total idleness, were due to such issues as grievances over physical working conditions, supervision, job assignments, workloads, pay methods, and many items other than wages and hours or union-organisation matters.

THE ADMIRALTY EXPERIMENT WORKS, TORQUAY.

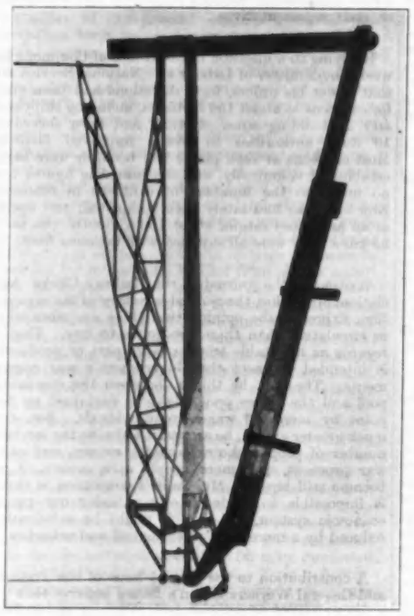


Fig. 1. Original Resistance Dynamometer.

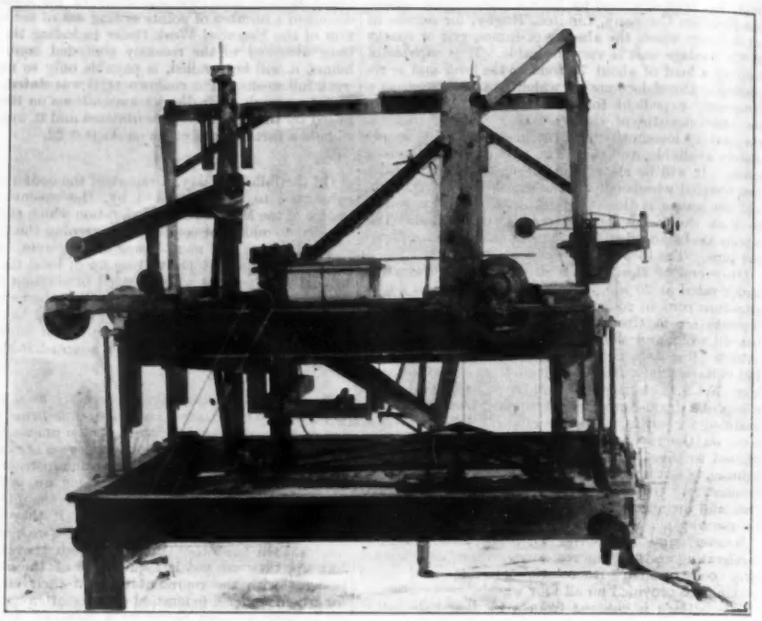


Fig. 2. Screw Dynamometer.

THE ADMIRALTY EXPERIMENT WORKS, TORQUAY.*

By R. W. L. Gawn, R.C.N.C.

The investigations carried out at Torquay by William Froude, who was a genius well ahead of his generation, not only placed the design of ship form and propellers and the rolling of ships on a sound basis and so led to improvements in naval architecture, thereby enabling the best use to be made of developments in propelling machinery and other branches of marine engineering, but also played an important part in stimulating interest in fluid flow and kindred problems generally. One may well pause to consider whether progress towards the development of those marvellous ships and aircraft of the present day would have been so rapid if the establishment of an experiment tank had been deferred until a later generation. Often, in the course of the author's official duties, it has been necessary to refer to reports of experiments at Torquay, and in the preparation of this paper the whole of these reports and correspondence has been reviewed. The opportunity of paying tribute to the careful manner in which these old records have been preserved and indexed for reference is gladly taken.

Descriptions of the Torquay Tank and equipment of contemporary date are contained in the *Proceedings* of the Institution of Civil Engineers and elsewhere,† but as these are not complete a short description of the tank is given in an appendix. The measuring apparatus was designed by William Froude and parts of it were executed by his own hand. Part of the original resistance dynamometer as used for the classical skin-friction tests and some of the earlier model experiments is still in existence (Fig. 1, on this page). This dynamometer was replaced in 1874 by a triangular trussed lever of thin wrought-iron channel bars mounted on knife edges, which is still in daily use as the resistance dynamometer of the first tank at Haslar, opened in 1887. The recording drum is also as made by Froude. Until 1938, too, the screw dynamometer, Fig. 2, on this page, of the small tank at Haslar was substantially as completed in 1873 by Froude, apart from the underhanging shafts and supports and certain other details. Another portion of the original apparatus, namely, the model-shaping machine, is also preserved. This was never used after the Torquay Tank was dismantled in 1886, but is in a good state of preservation. Mention should also be made of the squared-paper ruling machine which Froude evolved. Paper of the required accuracy was presumably scarcer in the 1870's than it is nowadays, and tradition has it that, despairing of finding paper sufficiently accurate for his purpose, Froude proceeded to make the simple but effective machine illustrated in Figs 3 and 4, opposite. This machine has continued in regular use since Froude's time, and now supplies the large requirements of the present day. The only alteration of note is the substitution of agate-pointed for steel pens and electric for steam drive. Haslar has a link with Torquay in that much of the "ball" clay still in use came from the deposits between Bovey Tracey and Kingsteignton in South Devon, which provided Froude from the beginning with the material for moulds in which the paraffin-wax models are cast. Another link with the past is the standard brass model, now 35 years old, which replaced a consecutive series of paraffin-wax standard models of H.M.S. Iris of 1878, a 300-ft. dispatch vessel. This model is run fairly frequently in the Haslar Tanks, and so connects present-day results with those of the early days at Torquay. As a further link with the past, a model was made in 1935 of the 1878 H.M.S. Iris, and tested for resistance. From the comparison between the resistance of this model in the large Haslar Tank in 1935 and that of the original model at Torquay in 1876 shown in Fig. 5, opposite, it is seen that there is fair agreement in the resistance qualities of the water in the two tanks.

Prior to the Nineteenth Century, naval architecture was, broadly speaking, a graceful art with little attempt at scientific ship design. Of the many facets of that art, resistance of ships appears to have been one of the most backward. Such ideas as obtained were for the most part fallacious and misleading. Deane and the Petts, in the Seventeenth Century, gave a great impulse to shipbuilding, but knowledge of resistance appeared to be confined to a more or less generally accepted assumption that the magnitude was proportional to the square of the speed and the sine of the angle of incidence of the portion of the surface under consideration. Newton's differential equation for the solid of least resistance was accepted as a guide by many until its underlying fallacy was appreciated years afterwards. Geometrical rules or the builder's batten were the only guides for ship's lines. Under the stimulus of awards by the French Academy of Naval Architecture, Bouguer, Bernouilli, and, in particular, Don Juan and Euler, among others, contributed elaborate theories which time has shown to be of no practical value. In 1763 some experiments by de Borda established the square law of velocity, but disproved the theory as regards oblique surfaces. These experiments deserve special mention as they formed a basis for further development and emphasised the need for replacing the obsolete theories. Further experiments were undertaken by d'Alembert, the Marquis de Condorcet, and the Abbé de Bossut in 1775, in which models were tested with many modifications to the extremities. They were towed by a line passing over a pulley at one end of a basin, the speed obtained when a series of different weights were hung on the end of the line being noted. The basin in which the tests were made was 100 ft. long, 52 ft. broad, and 6 ft. deep at its greatest part. Thus, the Torquay experiment tank was anticipated in an extremely primitive manner by nearly 100 years, but the work was not followed up. Great care seems to have been taken over the experiments, and the long report on them included the significant conclusion that, although the resistance increased nearly as the square of the velocity, it increased at a greater rate at high velocities. In 1783, Romme published the results of an extensive series of experiments before the Academy of Sciences which led to the formation of a committee to consider his results. By way of verification, a model of a French 74-gun frigate was tried in 1785 by Romme in a canal 40 ft. wide and 7 ft. to 8 ft. deep at Rochefort. The model was $\frac{1}{72}$ full size, the length being 14 ft. and breadth 3 ft. 8 in. One of the conclusions of Romme from his earlier experiments was the significant one that "the resistance upon the curvilinear bow of a ship is the same as if the immersed part of the body was formed by right lines drawn horizontally on the bow and terminated at the midship section." While this conclusion sounds rather odd nowadays, nevertheless the attention directed to the importance of the midship section was of lasting service.

It is very curious that French experimenters dismissed skin friction as of no importance compared with the "resistance against the bows," since, in 1796 to 1798, Colonel Beaufoy found in experiments at the Greenland Dock a formula for skin-friction resistance, and showed that it varied at a rate less than the square of the velocity. Beaufoy tested a variety of shapes of floating and submerged bodies and also plane surfaces, and some of his results have been substantially verified in more recent times. These tests, carried out under the auspices of the Society for Improvement of Naval Architecture, were of special merit. Chapman, the celebrated Swedish constructor, in his famous work published in 1806, deplored the negative results of the French experimenters and devised an elaborate and empirical method for evaluating the resistance of a ship. He also did some experiments on small models about the same time as Beaufoy's, and by the introduction of a rising floor, full bow, and fine after-body, it seems that some successful results were obtained. Mention of Chapman recalls that his famous countryman Emanuel Swedenborg is said to have suggested the use of experiment tanks for testing ship models in the Eighteenth Century, but, so far as is known, no

* Paper presented to the Institution of Naval Architects. Abridged.

† See *Proc. Inst. C.E.*, vol. 51, page 2 (1877); and *Proc. I.Mech.E.*, 1873 page 202; and 1884, page 190.

THE ADMIRALTY EXPERIMENT WORKS, TORQUAY.

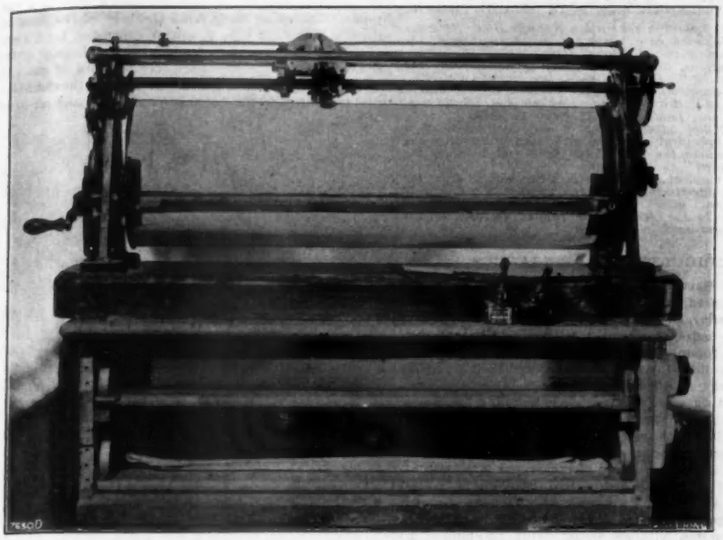


FIG. 3. SQUARED-PAPER RULING MACHINE.

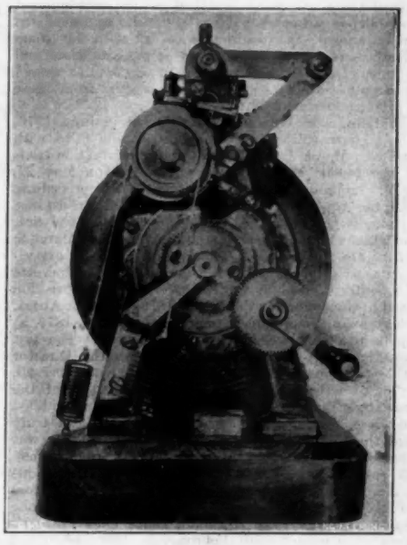
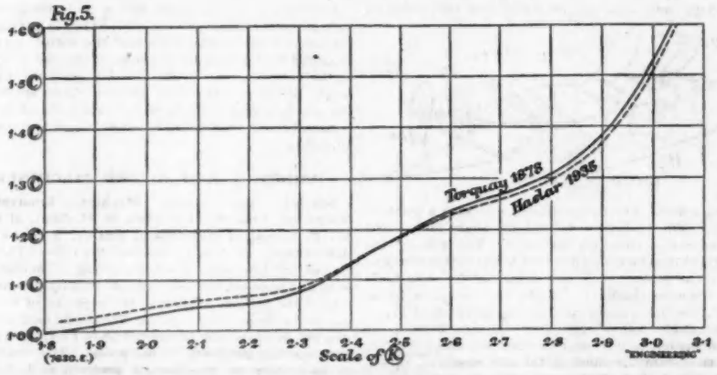


FIG. 4. END VIEW OF RULING MACHINE.



tests were carried out. Scott Russell's wave-line principle, enunciated in 1842, led to a reaction, and in consequence many ships with fine bows appear to have been favoured, although inconsistent with the results of both Chapman's and Beaufoy's experiments. Small wonder, then, that steamships were powered on the basis of the "Admiralty coefficients" (related either to displacement or midship section area) or similar empirical standard at about 1860, and that sail area was assessed in relation to the midship-section area. Steamship trials had indicated to some extent the importance of length of ship and of midship-section area, and even of depth of water, but the information was vague. Screw-propeller design also was distinctly empirical, and, according to a reliable writer in 1860, every shipyard had "piles of funny looking castings of all shapes and sizes, the produce of an incipient invention."

Such, in brief, was the state of the knowledge of resistance and propulsion in the middle of the last century. Many successful steamships and also sailing ships were built with fine bows and even hollow lines in accordance with the wave-line principle. This appeared to be a contradiction of existing model data, and was one of the circumstances leading to a fairly widespread distrust of model experiments. Scott Russell, among others, had made a large number of model experiments, but when he endeavoured to take advantage of those results which appeared to be favourable by applying them to his ships, the experience was generally discouraging, and he became a bitter opponent of model experiments. Apart from such essential practical objections, there were two main criticisms of model experiments in theory; first, it was alleged that models made proportionately larger waves than ships and, secondly, what was termed by Rankine the "rigidity" (now called "viscosity") of the water was more important the smaller the model. William Froude had been interested in naval architecture for many years, and the subject of ship-resistance was one which he had been independently investigating, both theoretically and experimentally. He played a leading part in interpreting the significance of Rankine's streamline ovals, formulated the streamline theory of resistance, and explained that the components of ship resistance were skin friction, wave-making and eddy-making, and assigned approximate values to these different components. Beaufoy's experiments had drawn attention to the importance of skin friction as noted above, but for years afterwards, and in fact until Froude's work on planks, there was much misconception and difference of opinion concerning the importance of skin-friction resistance.

Some of Froude's earlier experiments were made in the Dart above Totnes Weir, and in Bassenthwaite Lake, Cumberland, with small self-propelled models driven by clockwork of his own making. These are said to have been remarkable examples of his skill in the tinsmith's art, and his ingenuity in contriving delicate apparatus composed of pieces of tinned iron and solder, capable of yielding accurate results. At a later date, while living at Paignton and engaged upon building his house, Chelston Cross, at Cockington, Torquay, he found time for making some experiments on models towed in a fresh-water tank by a cord and falling weight, but soon came to the conclusion that such a method was unsatisfactory. No record of these tests can now be traced. The most important of his early experiments on resistance, however, were made in the mouth of the River Dart with three different sizes of model. These epoch-making experiments are described in greater detail below, because, although the results were imperfect in some respects, they were held by Froude to confirm his well-known law of comparison, enunciated in 1867. On April 24, 1868, William Froude, on the invitation of Mr., later Sir, E. J. Reed, Chief Constructor, outlined to the Admiralty his proposals for the construction of an experiment tank, and in December of that year forwarded a complete description with detailed estimates and proposals. Froude, who was then 58 years old, was most distinguished in scientific and naval-architecture circles, and was one of the original members of this Institution in 1860. Froude attributed the mistrust with which model experiments were regarded to the fact that the results were not interpreted at what he called the corresponding speeds, and considered that the viscosity objection could be overcome, provided the model was not less than 6 ft. long. Another important point stressed by him was the adoption of apparatus of sufficient delicacy. Experience was to confirm the great importance of each of these three factors, the first, based on Froude's Law of Comparison, being fundamental. This law, a special case of the Law of Similitude, was independently arrived at by Reech in France, but Froude's achievement was not only to prove and propound the law, but also to confirm it by practical experiment and so provide the means of interpreting ship model results. It is possible that model experiment investigations might have proved more fruitful before Froude's day if this important key had been available to open the way to their interpretation. A copy of Froude's Memorandum to the Admiralty in 1868 is published in Sir Westcott Abell's paper in 1934.*

While Froude's proposals were being considered, a committee appointed by the British Association in 1869 reported on various features of ship design; including resistance, and proposed full-scale towing trials on ships in a sheltered waterway. A minority report was rendered by one member of the committee, namely, William Froude. It is curious that Froude does not seem to have been aware, until the draft report was in his hands, that the subject of resistance was regarded as included in the list of subjects submitted to the committee. It appeared to him to belong to the "Steamship Performance Committee," and he found himself "somewhat abruptly placed in a position in which I must ask permission to present, as part of our proceedings, a supplementary report explaining the reasons which obliged me to dissent from the recommendations to which I refer." Froude concurred in the desirability of ship-towing trials, but considered model experiments would be more fruitful of results in the long run. Eventually, in February, 1870, about fourteen months after the original proposal was received, the Admiralty decided to give the idea a trial. In accordance with Froude's proposals, expenditure was limited to 2,000*l.*; the work of building the tank and carrying out the experiments was to be completed in two years, and was to include rolling as well as resistance experiments. Froude's services as designer of the tank, and as superintendent and mechanic—he made some of the apparatus himself—were given gratuitously. Preliminary experiments were made in 1871, and by 1872 work was in full swing. The success of the project was never in doubt. It was a triumph for Reed

* *Trans. I.N.A.*, vol. 76, page 243 (1934).

as well as for Froude, and also for the Controller of the Navy at the time, Sir Spencer Robinson. The Government of the day was very sparing of expenditure, and the opinion among naval architects and the British Association committee was almost unanimously opposed to model experiments. When Admiralty approval was made known, the decision was criticised by some members of this Institution as a waste of time and money. Despite this, great confidence was expressed in Froude's ability to derive good results from these "pretty experiments."

Building work commenced on the site in June, 1870. The waterway was dug out, puddled, and filled with water by March 21, 1871, and the first calibration trials of the towing carriage were carried out on May 22, 1871. Preliminary runs to ascertain the best procedure, and the type and size of springs for the resistance dynamometer, occupied a few months, and the first model, of a modified Greyhound, was tested on March 3, 1872. On August 15, 1873, the first propeller experiments were made behind a model of the corvette Encounter. Tests continued under Froude's direction until his departure at the end of 1878 for South Africa, where his untimely death occurred on May 4, 1879, at the zenith of his wonderful achievement. The last investigation reported upon by him to the Director of Naval Construction was that dated November 20, 1878, of experiments made with the model of the Inflexible, to ascertain her trim under way in a riddled and waterlogged condition. He had well and truly laid the foundations of model experiments. He was succeeded by his second son, R. E. Froude, then 33 years of age. Robert Edmund had assisted his father since the inception of the tank, and events were to show that the succession had passed from one genius to another. R. E. Froude continued his father's work at Torquay until February 3, 1886, when the lease of the land on which the experiment-tank building was situated expired and a new site was found at Haslar. Some of the equipment was transferred to Haslar, notably parts of the resistance dynamometer, practically the whole of the screw dynamometer, and the paper-ruling machine. Much new equipment was specially made to replace the Torquay apparatus, which was largely of a provisional character in compliance with the terms of the Admiralty letter approving the Torquay Tank. The expenditure had been limited to 2,000*l.*, and the work was to have been completed in two years. It is seldom that such a cautious provision can have been proved by the event to have been so completely inadequate. Yet the records contain no hint, either from William Froude, Sir Nathaniel Barnaby, the Chief Naval Architect at the time the project was approved, or others concerned, that it would ever be necessary to extend the duration of the tests and expand the grant.

The ultimate life of the Torquay Tank extended over 14 years, and shortly before it was dismantled a second and similar tank was opened at Dumbarton, in 1884. The Admiralty Establishment, which was opened at Haslar in 1887, has been in regular and constant operation continuously since that date, and, in addition, another and larger experiment tank was opened on an adjacent site eight years ago. Although there are now six other experiment establishments in the country and upwards of 50 throughout the world, it was a long time before other countries were convinced of the advantages of model tests, since, even at the end of the last century, after 30 years' experience of the system, there were only five tanks in the world. There is scarcely a volume of the *Transactions* of this Institution and kindred societies which does not contain some account of the work at an experiment tank. Problems of hull form, appendages, propellers, and weapons of great complexity and variety are being continuously investigated. The work at Torquay, originally intended to be completed in two years, occupied the last eight years of W. Froude's life, 48 years of his distinguished son's life, and a great amount of activity of experimenters over the whole world. Truly, a wonderful harvest from such a tiny seed, exceeding by far the intensive imagination of the great pioneer and those associated with him in the responsibility for the undertaking.

(To be continued.)

CEYLON MOTOR-VEHICLE IMPORT RESTRICTION.—The shipping to Ceylon from any source, as from July 18, of motor cars, lorries, vans, omnibuses and tractors is now prohibited except under licence.

THE PANAMA CANAL RECORD.—The Editor of the monthly U.S. Government official journal, *The Panama Canal Record*, informs us that the publication of this statistical periodical has been discontinued until further notice. The last issue was that dated April 30, 1941 (volume 34, No. 9), which dealt with traffic passing through the Canal in March, 1941.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.

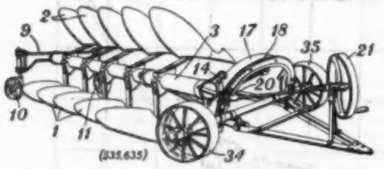
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

AGRICULTURAL APPLIANCES.

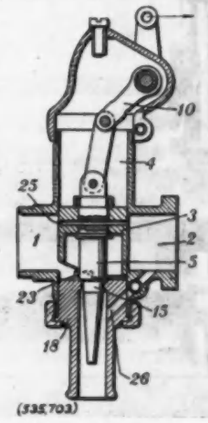
535,635. Reversible Plough. Ransomes, Sims and Jefferies, Limited, of Ipswich, A. J. Hosier, of Marlborough, and A. Whatley, of Newbury. (4 *Figs.*) December 19, 1939.—Five pairs of right- and left-hand share bodies 1 and 2 are mounted on a tubular longitudinal beam 3. The share bodies of each pair are secured to it by arms, approximately at right angles to each other, the arms being fixed to a screw clamp tightly gripping the beam. The rear end of the beam has a pivot pin mounted in a central bearing in the rear-carriage, consisting of a cross-bar 9 supported on castor wheels 10 and 11. The fore end of the beam 3 has a spider carrying a pinion 14. This end of the beam also has two guide rollers running on an arcuate cam track 17, the sides of which are of steeper curvature than the upper part. The pinion 14 meshes with an arcuate rack 18 clamped to the fore-carriage 20, and is rotated by a handwheel 21. Assuming that the right-hand share bodies 1 are in position for ploughing, as shown, the wheel 34 of the fore-carriage acts as a furrow wheel and the other 35



as a land wheel. The rear carriage is in such a position that the castor 10 follows behind the share bodies and the other castor rides on the land. The axle of the castor wheel 10 is locked, while that of the castor wheel 11 is free. The pinion 14 is low down on the right-hand side of the cam track 17. When the plough is to be reversed, the ploughman rotates the handwheel 21, so that the guide rollers ride over the track from the right- to the left-hand side, carrying with them the fore end of the beam 3, which is thus rotated and raised, with the result that at the central position the plough is in its transport position with both sets of the bodies 1 and 2 raised from the ground. When the rollers reach the end of the track the reversal is complete. The left-hand share bodies 2 are then brought into the operative position, in correct relation to the line of draught. When the plough is drawn forward, the left-hand wheel 35 of the fore-carriage acts as a furrow wheel and the other as a landwheel. Similarly, the left-hand castor wheel 11 of the rear-carriage follows the line of the left-hand share bodies and is locked, and the other rides on the land and is free to castor. (*Accepted April* 16, 1941.)

INTERNAL-COMBUSTION ENGINES.

535,703. Gas-Fuel Carburettor. Amal Limited, of Perry Barr, and C. Brown, of Sutton Coldfield. (3 *Figs.*) October 13, 1939.—The main object of the carburettor is to ensure the correct ratio of gas to air under varying conditions of speed and load of the engine. The air intake 1 is co-axial with a horizontal main mixture passage 2 communicating with the induction pipe of the engine. A piston valve 3 slides in a cylindrical passage and carries a needle valve 5. This latter passes through and is secured to the crown of the piston. Above the piston, it is coupled by a connecting link to a crank 10 housed within the upper portion of the passage 4 and a domed cap. The needle valve has a parallel portion 15 of reduced diameter forming a shoulder and is tapered towards its extremity. The co-operating block 18 of the needle valve is housed within the lower portion of the passage and is retained in position by a union nut. The upper end of the block is bored to take the narrower cylindrical portion of the needle valve with play, and the lower end is shaped for the attachment of a pipe for the supply of gas. A semi-circular baffle 23 is formed on the face of the valve block 18 around the needle valve on the air intake side so that the incoming air stream passing over this baffle creates a partial vacuum and further increases the depression in the immediate locality of the valve. The skirt of the piston valve 3 is partly cut away on the air intake side to provide a larger aperture than on the opposite side of the valve which controls the flow of mixture to the engine. An air-bleed 25 is bored through the crown of the piston and the needle valve. A fuel by-pass channel 26 leads from the bore of the block 18 into the induction pipe 2, and is controlled by a screw valve. In the valve position shown, the shoulder of the needle valve 5 cuts off completely the flow of gas. In this position gas and air for slow running of the engine are provided through the by-pass passage 26 and air-bleed



passage 25, respectively. When the piston valve and needle valve are raised to a slight extent, a limited quantity of gas flows past the part 15 of the needle valve. During this early movement of the piston and needle valve a high pressure difference is maintained in the mixing chamber around the needle valve and the correct mixture is provided by limiting the opening of the fuel valve. On further opening of the throttle the pressure difference begins to fall and the taper portion of the needle opens the aperture progressively so that the ratio of air to gas is maintained substantially constant. (*Accepted April* 18, 1941.)

PRINTING AND ALLIED MACHINERY.

535,792. Slug-Casting Machine. Linotype and Machinery, Limited, of London, R. H. Scott, of Enfield, W. F. Gorse, of Altrincham, and A. S. Hayward, of Altrincham. (5 *Figs.*) October 20, 1939.—The invention is a Linotype machine having a mould carrier with an increased capacity without unduly increasing the size of the carrier. Hitherto the capacity of the mould carrier has been 2 or 4 moulds. The mould carrier consists of a flat substantially hexagonal plate 1 having six mould seatings 2 formed on its periphery. The seatings are divided from one another by projections 3 shaped to

Fig. 1.

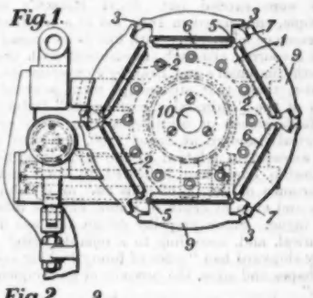
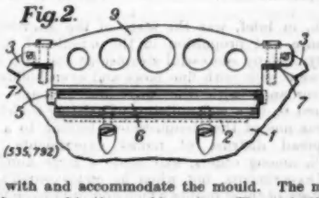


Fig. 2.



engage with and accommodate the mould. The mould body 6 is screwed to the mould carrier. The projections 3 have a ledge to accommodate liners 5, against which the body of the mould 6 rests, and a gap 7 is left to allow the mould cap 9 to be clamped down by bolts to the carrier and in correct relation to the body 6. The mould cap is adjustable so that the height of the mould aperture can be varied. The mould carrier 1 is mounted on a shaft 10 driven from the main drive of the machine. Provision is also made for manual rotation of the mould carrier. (*Accepted April* 22, 1941.)